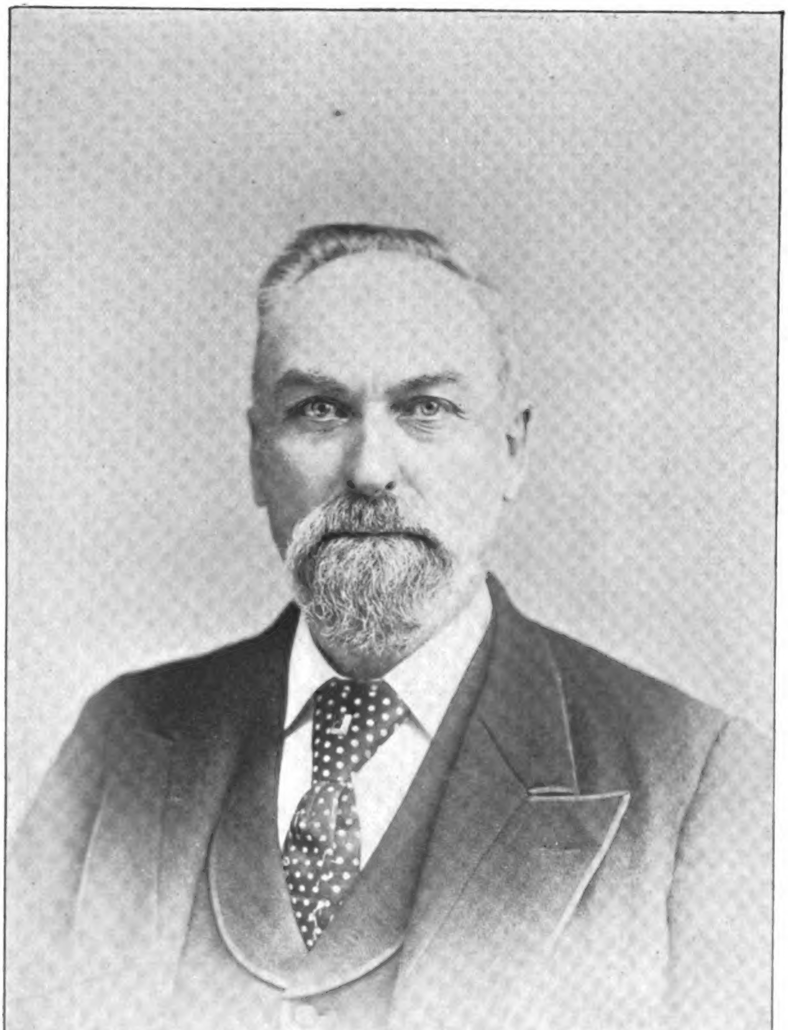

Very truly,
Jn. Sutton.

COKE.

A Treatise on the Manufacture of Coke and the Saving of By-Products.

WITH SPECIAL REFERENCES TO THE METHODS AND OVENS BEST ADAPTED TO THE PRODUCTION OF GOOD COKE FROM THE VARIOUS AMERICAN COALS.

BY

JOHN FULTON, E. M.

Member of American Institute of Mining Engineers, American Philosophical Society of Philadelphia, etc., etc.

SCRANTON, PA.

The Colliery Engineer Co.

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INDEX.

PREFACE.

The manufacture of coke, in the United States of North America, began in a feeble way, with four small establishments, in the year 1850.

During the thirty years following, its progress was rather slow; but from 1880 to 1892 it made rapid advances, showing in the latter year 261 establishments, using 42,002 coke ovens and producing 12,010,829 tons of coke, valued at $23,536,141.00 at the ovens.

In the year 1869, the use of coke in blast furnaces outranked that of charcoal, and in 1875, surpassed anthracite coal.

Since the latter date, it may be said that we have fully entered into the *Era of Coke.*

It is also evident that this coke fuel is destined to retain this leading place of usefulness in metallurgical operations, and its increase is destined to accompany the expansion of the iron and steel industries.

In considering the present condition and future requirements of the coke making industry, with its paramount value in the manufacture of iron and steel, it appeared that a volume embracing the principles and practice of the manufacture of coke would prove of permanent value to those engaged in these correlated industries.

Its publication is regarded as the more needful at this time, on account of the efforts being made to introduce the modern types of retort coke ovens, with their auxilliary apparatus for saving the chief by-products, of tar and sulphate of ammonia, from the gases expelled in coking, and thus supplement the profits in the coke industry.

In the United States, the manufacture of coke has hitherto been confined mainly to localities affording the best qualities of coking coals.

It required little skill to make excellent coke from such good coals. But with the large expansion of the production of coke, and the gradual exhaustion of the areas of the prime coking coals, compelling the use of the secondary qualities of coking coals, a thorough study of the merits of the several kinds of coke ovens now being offered, is regarded of the most important interest.

In this volume, the papers on the manufacture of coke, which have been published in "The Colliery Engineer and Metal Miner," have been recast and carefully revised. They exhibit the several methods of coking, with accurate results, for the consideration of those interested in this industry.

The author feels that very much remains to be learned in this department of industrial art; but trusts that this initial volume will suggest matter that will lead to an accelerated advance in useful knowledge, along the several sections embraced in its pages.

The work has been undertaken with a feeling of the difficulty of doing it the justice its importance deserves. But in this respect the author trusts that some truth has been gleaned under the conditions of the old adage, that, "necessity is the parent of invention."

In the twenty years' experience of the author, in his official position of General Mining Engineer and General Manager of the Cambria Iron Company, he has been required to study the manufacture of coke in its elements of quality and cost.

The extensive operations of this company, in the different sections of the Appalachian Coal region, by several methods of coking, afforded desirable opportunities for investigation and for the comparison of results.

In the year 1875, the coke made at the works at Johnstown, in Belgian coke ovens, failed to meet the furnace requirements.

The management requested an investigation of the cause or causes of the inefficiency of this fuel in blast furnace work.

It appeared at first to be an easy task to ascertain the nature of the defect or defects in this coke. It was assumed that a chemical analysis would disclose the whole matter; but contrary to expectation, it did not; it showed the coke to be very pure, with much less ash than the Connellsville, and with marked exemptness from other injurious elements.

The result compelled an expansion of the method of investigation, as the chemical method alone would not reveal the cause.

A study to devise a method for the physical examination of the coke was then entered upon, which, after many trials, resulted in developing a plan that disclosed the main cause of the failure of this coke for blast furnace use—its want of the principal requirement, "*hardness of body.*"

From the softness of the body of this coke, much of it was wasted in the upper section of the blast furnace, by dissolution in the bath of the ascending carbon dioxide gas, thus lowering the temperature at the zone of fusion, and disarranging the regular operations of the workings of the furnace.

These early methods of testing the physicial properties of coke were very crude and open to criticism, but the urgency of necessity, it is believed, has ultimately disclosed accurate methods of determining the true value of coke for metallurgical uses; the practical results in furnace work sustaining the reliability of these determinations.

It has become evident in the manufacture of coke from the secondary qualities of coking coals, that from the nature of the requirements of quick and high oven heat to secure the hardest bodied coke possible from such coal, the retort type of coke ovens will have to be used.

It is confidently hoped that the plans and statements of the actual work of these retort ovens, with and without apparatus for the saving of by-products, will prove helpful in enabling the coke manufacturer to make intelligent selection and application, of the special type of oven best adapted to assure the best coke from the coal used in its manufacture.

Very much care has been given to the consideration of the best modern methods in the preparation of coals for coking; especially in the processes of crushing and washing, with the elimination of slates and pyrites.

In the preparation of this work, the author has necessarily drawn from many sources; care will be given to render due acknowledgments for such help, when possible to do so.

He is laid under many obligations to Mr. Joseph D. Weeks, of Pittsburgh, for extracts from his admirable reports and statistics of the manufacture of coke, and the results of his recent visit to Europe. Mr. Walter M. Stein, metallurgist, Philadelphia, agent for the Siebel retort coke oven, has kindly contributed many papers on plans and work of coke ovens.

Dr. F. Schniewind, of Cleveland, Ohio, agent of Dr. C. Otto and Co., has generously contributed very full information of the plan, cost and work of the Otto-Hoffman oven.

Mr. W. B. Cogswell, general manager of the Solvay Process Co., of Syracuse, N. Y., has kindly contributed plans and results of the working of the plant of Semet-Solvay coke ovens, at his place.

He is also placed under renewed obligations to Sir Isaac Lowthian Bell, of England, for plans of his Browney coke ovens, and for his admirable method of testing the resistance of coke to the action of carbon dioxide.

Mr. Henry Aitken, Falkirk, Scotland, has kindly contributed his plans and studies, in his methods of saving by-products from Bee-Hive ovens.

The Mineral Statistics of the United States by Dr. David T. Day, of Washington, D. C., have afforded much help in many ways.

He is also greatly indebted for matter gleaned from the works of the Second Geological Survey of Pennsylvania, by Prof. J. P. Lesley, State Geologist, and his able assistants.

Many valuable extracts have been made from the several volumes of the transactions of the American Institute of Mining Engineers.

Sincere thanks are returned to the many others who have so kindly contributed to the matters in the pages of this volume.


MAP
showing the known
COAL FIELDS
OF THE
UNITED STATES
with contiguous Canadian and Mexican fields
John Fulton E.M.
1894
LEGEND
Coal Fields
Mountains
ATLANTIC OCEAN
PACIFIC OCEAN
GULF OF MEXICO
GULF OF CALIFORNIA
CANADA
MEXICO

CHAPTER I.

THE COAL FIELDS OF THE UNITED STATES.

Special periods of Coal Making.—The value of this Fuel Supply to Man.—The Standard of Wealth and Power of Nations.—Comparative Areas of the Coal Fields of the World.—The United States Greatly Favored.—Coal Production of the Nations of the World, 1893.—Place of Coal Amongst the Rocks.—Qualities of Coal in the Different Periods of Deposit.—The Flora of the Coal Periods.—(I.) The Anthracite Fields of Rhode Island, Massachusetts, Pennsylvania and Colorado.—Their Areas and Typical Analyses.—(II.) The Appalachian Coal Field the Largest in the World.—Great Depository of the Coking Coals.—Areas in Pennsylvania, West Virginia, Kentucky, Tennessee, Ohio and Alabama.—Analyses of the Different Qualities of Coal.—(III.) The Northern Coal Field.—Michigan.—Its Character and Extent.—Analyses of Coal.—(IV.) The Central Coal Field.—Indiana, Illinois and Western part of Kentucky.—Area.—Analyses of Coal.—(V.) The Western Coal Field, Iowa and parts of Nebraska, etc.—Area.—Analyses of Coal.—(VI.) Rocky Mountain Coal Field.—Mainly Cretaceous-Laramie.—Dakotas, Montana, Idaho, Wyoming, Utah, Colorado and New Mexico.—Area large, but not well defined.—Analyses of Coals.—(VII.) The Pacific Coast Field.—Washington, Oregon and California.—Detached Fields.—Cretaceous and Tertiary Coals.—Area not defined.—Typical Analyses of Coals.—Table Showing Areas and Products of these Coal Fields in 1893.—Table Showing Coke Product and Values in 1893.—Canadian Coal Fields.—(I.) Nova Scotia and New Brunswick.—(II.) British Columbia and Vancouver's Island.—(III.) Plains of Rocky Mountains.—Typical Analyses of Coals.—Mexico.—Coahuila.—Hondo.—Analyses.

Geology, like history, has its special and important epochs.

The coal making periods are the most remarkable in the geology of our planet. During these times, the great deposits of mineral fuel were stored up, anticipating and providing for the wants of the coming man; in the order of his comfort, civilization and power.

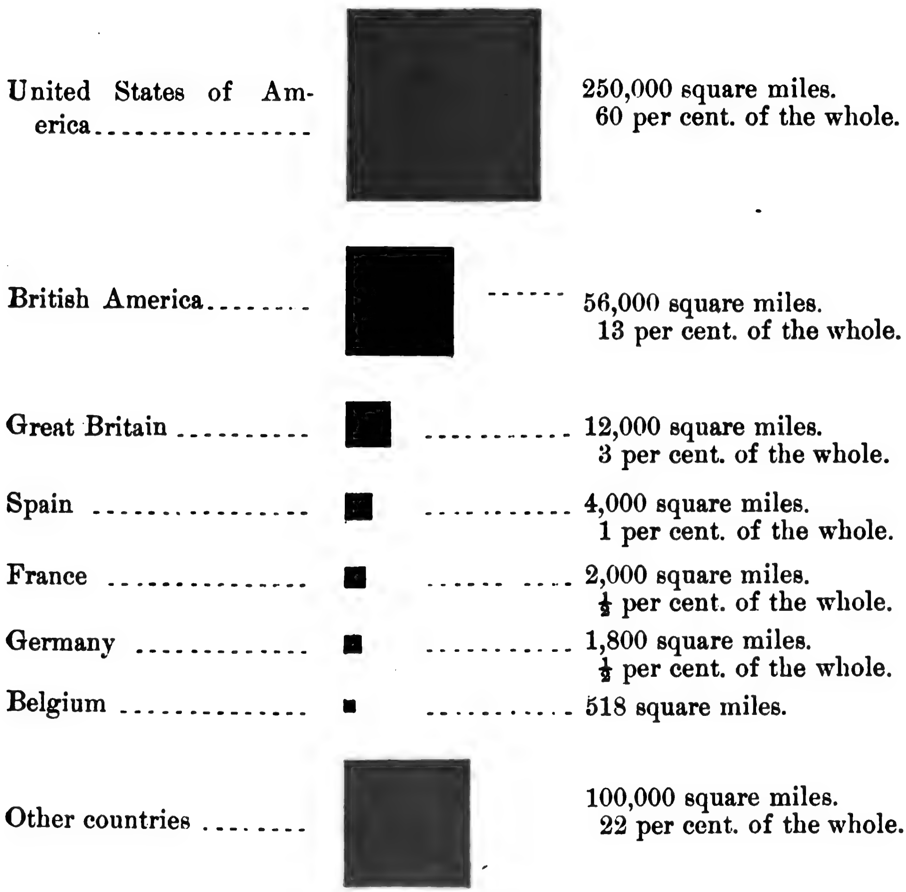
Amongst all the valuable gifts the Creator has bestowed upon man, coal is the most essential to his well being and progress.

It is true that man could exist, under the beneficence of the sun's warmth and the fuel from the vegetation of the field and forest; but it is clearly evident that to attain the best conditions of civilization and power, he must have the fuel supply of the stored up and crystalized sun-light, of the old time coal making periods.

The value of this coal endowment has now become a standard by which the nations of the world are classified as to their present power and future progress.

From our present knowledge of the extent of the coal fields of the nations of the world, the following graphic comparison will exhibit their relative ranks in their possessions of coal.

COAL FIELDS OF THE WORLD.



The above comparison of coal areas exhibits the fact that the United States of America inherit a wealth of mineral fuel largely exceeding that of any other nation.

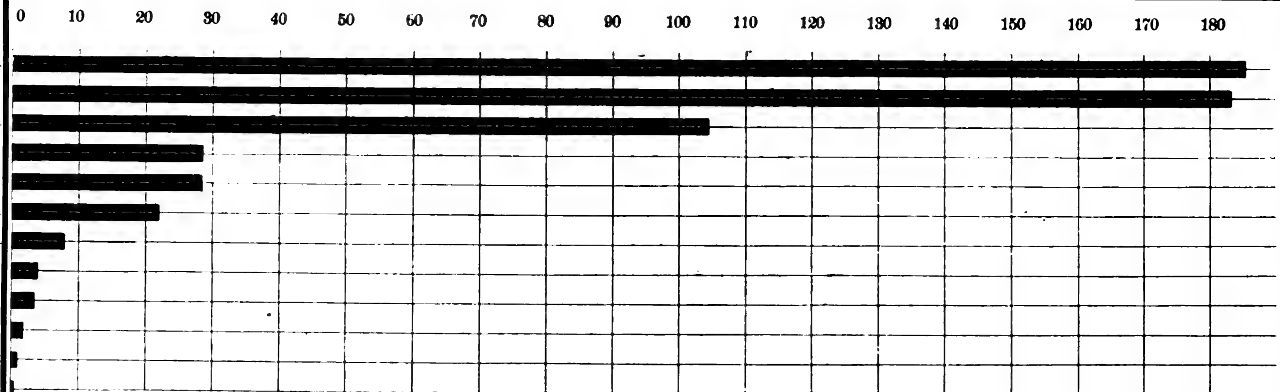
Future explorations will likely increase the areas of coal in the United States and in the Dominion of Canada.

The following statistical diagram will show the relative product of coal by the several nations of the world:

THE WORLD'S PRODUCT OF COAL.

COUNTRIES.	NET TONS.	YEAR.
Great Britain.......	184,044,890	1893
United States......	182,352,774	1893
Germany..........	103,851,090	1892
France............	28,862,017	"
Austria............	28,037,678	"
Belgium	21,[illegible]90,448	"
Russia............	7,621,969	"
Canada	3,719,170	1893
Japan	3,400,000	"
Spain	1,688,820	"
New Zealand	673,315	1892
Sweden	421,115	"
Total	566,589,666	

MILLIONS OF TONS.



Per centage of England..... 32.5
" " United States 32.0
" " Germany..... 18.0
" " France....... 5.0
" " Austria...... 5.0
" " Belgium..... 4.0

The marginal columnar section will show the places of the coal amongst the rocks.

And whilst it has had three periods of greatest deposit, yet the evidence, in the remains of plants from the Laurentian to the Tertiary, shows that plant life, in greater or less degree of development, accompanied all the sedimentary deposits.

The remains of this vegetable growth are found in the Laurentian in the mineral *graphite*.

It is usually associated with folded and flexed strata.

In the lower coal measures, eastward, which are also greatly compressed and flexed, anthracite coal is the product of this old age flora.

Westward, in this carboniferous period, under modified conditions of rock flexure, the rich bituminous coals are the crystallized remains of the luxuriant flora of this epoch.

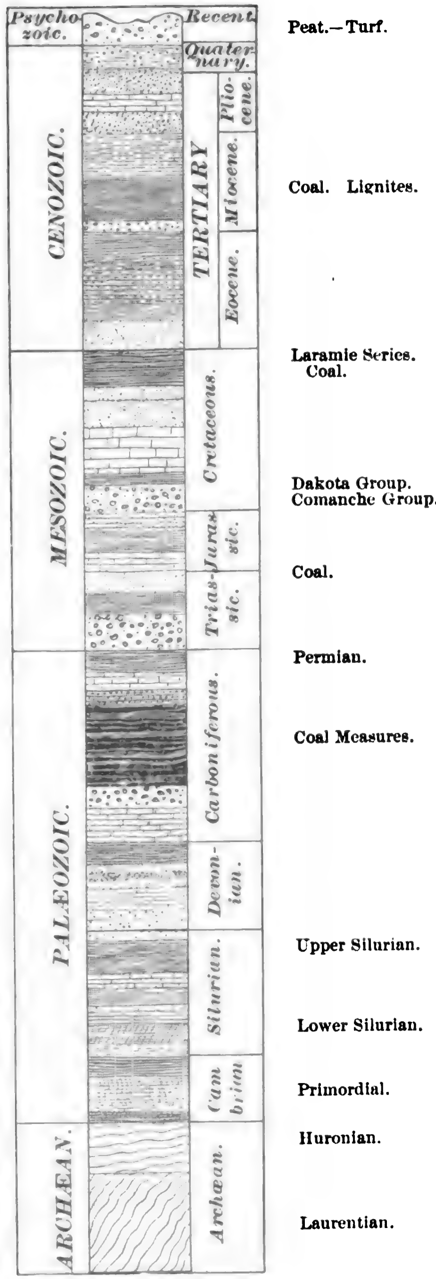
Farther westward, in the Jurassic, Cretaceous and Tertiary periods, bituminous and lignite coals are found, as the results of the recurrences of the periods of the coal-making flora.

The more recent vegetable deposits found in the peat or turf bogs afford interesting and suggestive examples of the genesis of coal.

Its flora, however, exhibits newer forms and conditions from the old time periods of the coal making plants.

The map of the United States, with portions of Canada and Mexico, preceding this chapter, will show the location and extent of the known coal fields within these bounds.

They are usually classified in the United States under seven main sections in the following order:



Section showing the places of coal in the rocks.
—Le Conte.

I.—THE ANTHRACITE COAL FIELDS.

These embrace, in the aggregate, an area of about 1,008 square miles.

The extreme eastern anthracite field, lying mainly in Rhode Island, with its north end resting in Massachusetts, contains about 500 square miles of coal measures. It affords peculiar varieties of anthracite and graphitic coals. It contributes a small output to local markets.

In northeastern Pennsylvania the triple anthracite fields cover an aggregate area of 488 square miles. These three regions, the Schuylkill, the Lehigh and the Wyoming, with their small annexes, contain mammoth beds of pure, glassy anthrácite coal, with thicknesses of 3 feet to 60 feet.

The annual aggregate output in 1893 reached the large sum of nearly 54,000,000 tons, valued at $85,687,078.00.

The small anthracite field of Sullivan County, Pennsylvania, with the anthracite patches in the States of Colorado and New Mexico, cover an aggregate area of about twenty square miles.

The elementary composition of these coals in the anthracite fields will be readily seen from the average proximate analysis of each section, given below:

	Rhode Island.	Massachusetts.	Pennsylvania.	Colorado.
Moisture	8.36	2.05	2.98	3.42
Volatile Matter	6.09	4.99	3.38	8.76
Fixed Carbon	73.23	76.96	87.13	78.87
Ash	11.68	15.44	5.86	8.30
Sulphur	0.64	0 56	0.65	0 65

II.—THE APPALACHIAN COAL FIELD.

The Appalachian coal field is the largest and most liberally endowed coal field in the world. It lies along the western side of the Appalachian mountains, and has a general posture southwestward. The northern end, with its terminal fingers and outlying coal fields, rests in northwestern Pennsylvania, nearly touching the New York State line. The southern end rests in the State of Alabama. It has a length somewhat over 900 miles, with a width of 30 to 180 miles.

It covers in its broad southwestward course portions of the states of Pennsylvania, Ohio, Maryland, Virginia, West Virginia, Kentucky, Tennessee and Alabama.

The general trend of its eastern border approximates to a conformity with the shore line of the Atlantic Ocean.

The coal measures belong to the Carboniferous proper, and have an aggregate thickness, from a few hundred feet to three or four thousand feet.

West Virginia is credited with inheriting the maximum depth of coal measures.

The coal beds vary from a few inches to ten feet or more. The percentage of coal to its associated rocks and shales is usually estimated as one foot of coal to fifty feet of slate and rock measures.

The area of this coal field is 64,395 square miles.

The following series of analyses will exhibit the average composition of its coals.

	Pennsylvania.		Ohio.	West Virginia.		Kentucky.	Tennessee.	Alabama.
	East.	West.		East.	West.			
Moisture	1.73	1.70	1.58	1.52	1.52	1.80	1.50	1.65
Volatile Matter	23.89	39.15	41.86	19.81	37.86	33.00	32.51	32.48
Fixed Carbon	67.03	46.66	51.44	72.71	53.37	60.10	59.33	60.15
Ash	6.69	10.52	5.12	5.20	6.03	5.10	5.82	4.82
Sulphur	0.66	1.97	2.64	0.76	1.22	0.65	0.84	0.90

III.—THE NORTHERN COAL FIELD.

The Michigan coal field, in the middle of that state, covers an area of 6,700 square miles.

The coal measures have been found comparatively thin and irregular. In Jackson and Shiawassee counties, the coal beds have thicknesses from 2½ feet to 3½ feet. The output of coal from this field is limited, and mainly confined to local consumption.

ANALYSIS OF JACKSON COUNTY COAL.

Moisture	2.00
Volatile Matter	49.00
Fixed Carbon	45.00
Ash	2.00
Sulphur	2.00

IV.—THE CENTRAL COAL FIELD.

This large central coal field embraces the bituminous, block and cannel coals in the states of Indiana, Illinois, and the western section of the Kentucky coal.

It has an area of about 47,250 square miles.

The main portions of the coals of this field are rich in bituminous matter. The "block coal" of Indiana is a peculiar fuel. In coking, its volatile matters are expelled, leaving the normal structure of the coal intact. In this condition it is simply a "*charred coal.*"

The Illinois coals are not regarded favorably for the manufacture of coke, from their richness in fusing matter producing a spongy coke; but for all other uses they are marketed in large quantities.

ANALYSES OF CENTRAL FIELD COALS.

	Indiana.		Illinois.	Kentucky.	
	Bituminous.	Block.	Jackson Co.	Bituminous.	Cannel.
Moisture	2.98	2.10	2.08	4.48	1.46
Volatile Matter	40.98	39.05	37.10	32.22	45.35
Fixed Carbon	50.70	55.20	52.17	54.08	45.80
Ash	3.46	2.90	7.02	7.90	6.63
Sulphur	1.88	0.75	1.63	1.37	0.76

V.—THE WESTERN COAL FIELD.

The western coal field occupies the southern portion of the State of Iowa, the southeastern corner of Nebraska, the northwestern section of Missouri, the eastern side of Kansas, passing through the eastern portion of the Indian Territory and resting in a great prong in the middle of the State of Arkansas.

It occupies the interior plain of the continent.

It has an area of 98,700 square miles of coal measures.

Recent explorations in the Indian Territory have developed large beds of coal fairly well adapted to the manufacture of coke.

Extensive mining operations are carried on in the states of Iowa, Missouri and Kansas.

AVERAGE ANALYSES OF COALS.

	Iowa.	Missouri.	Nebraska.	Kansas.	Indian Territory.		Arkansas.	
					East.	West.	East.	West.
Moisture	3.00	6.50	....	3.25	1.05	1.79	1.02	1.05
Volatile Matter	38.25	37.71	....	40.96	19.04	40.20	10.49	14.65
Fixed Carbon	48.50	42.17	....	43.98	71.78	51.79	76.12	76.11
Ash	7.50	10.56	....	10.71	7.53	4.88	9.96	6.63
Sulphur	2.75	3.06	....	1.10	0.65	1.34	2 41	1.56

The Texas coal field belongs, by geographical position, to the western field. Prof. E. T. Dumble, State Geologist, in regard to these lignites states: "It should, however, be plainly understood in the beginning, that the brown coals of Texas will be found to differ very widely in quality, and it will require analysis of each deposit to tell with certainty for what purpose it is best adapted."

ANALYSES OF BROWN COALS OF TEXAS.

	Stevens.	Eagle Pass.	Laredo.	Bowie Co.
Moisture	10.00	5.27	2.00	10.32
Volatile Matter	35.81	37.48	50.05	76.35
Fixed Carbon	48.46	44.46	39.10	11.53
Ash	4.20	10.22	7.35	1.45
Sulphur	1.53	2.57	1.50	0.35

VI.—ROCKY MOUNTAIN COAL FIELDS.

The Rocky Mountain coal regions cover portions of Dakota, Montana, Idaho, Wyoming, Utah, Colorado and New Mexico.

The coal fields in this territory embrace the deposits on the flanks of the Rocky Mountains. The main areas of coal, developed at this time, are found in the eastern side of these mountains.

The qualities of these coals are quite varied, including the Permo-Carboniferous, the Jura-Trias, with the Laramie, the Cretaceous and the Tertiary.

Some of these coals make good coke, but many of them will not fuse in a coke oven.

Several of the beds are quite thick, and afford valuable fuel for generating steam, and for metallurgical, manufacturing and domestic uses.

This section of coal deposits is in progress of development and exploration by the Government officials, as well as by private enterprise, and this is adding to its enlargement of area and the value of the coals.

ANALYSES OF REPRESENTATIVE ROCKY MOUNTAIN COALS.

(Mainly Lignites.)

	Dakota.		Montana.		Idaho.	Wyoming.	Utah.	Colorado.		New Mexico.
Moisture	3.12	11.53	2.16	2.82	11.43	8.10	6.00	2.49	0.95	2.56
Volatile Matter	23.08	44.06	20.98	22.51	39.52	34.70	39.75	36.20	29.82	35.20
Fixed Carbon	59.27	35.74	70.16	63.30	38.26	51.65	47.65	54.82	56.41	50.12
Ash	13.87	8.67	6.35	10.53	9.45	5.55	6.05	6.48	12.82	10.76
Sulphur	0.66	0.72	0.35	0.84	1.34	....	0.55	0.06	0.41	1.36

Some of these coals will make coke. The larger portion, however, do not fuse in the coke oven.

VII.—THE PACIFIC COAST COAL FIELD.

The Pacific Coast coal field embraces a number of detached fields in the states of Washington, Oregon and California. Twenty-three coal beds of different thicknesses have been developed, all lignite or brown coal.

In western Washington some seams of bituminous coal have recently been found which are reported as well adapted for the manufacture of coke. Also in eastern Washington coking coals have been developed.

In addition to these fusing or coking coals found in this field, the chief varieties of coals are valuable for industrial and domestic purposes.

ANALYSES OF THE PACIFIC COAST COALS.

	Washington.		Oregon.		California.	
Moisture	2.36	1.74	20.00	1.53	15.50	18.08
Volatile Matter	41.91	30.70	32.50	38.33	40.00	39.30
Fixed Carbon	48.65	58.30	41.96	44.94	29.50	35.61
Ash	7.08	9.26	5.84	10.71	15.00	7.01
Sulphur	....	....	....	4.49	....	....

Tabulated statement exhibiting the extent and products of the coal fields of the United States, 1893.

	NAME OF COAL FIELD.	Area. Square Miles.	Output of Coal. 1893. Net Tons.	Output of Coke. 1893. Net Tons.
Carboniferous.	ANTHRACITE.—I.			
	Rhode Island and Massachusetts	500	....	....
	Pennsylvania	488	53,967,543	....
	Colorado and New Mexico	20	93,578	....
	Totals	1,008	54,061,121	....
	APPALACHIAN.—II.			
	Pennsylvania	9,000	44,070,724	6,229,051
	Ohio	10,000	13,253,646	22,436
	Maryland	550	3,716,041	....
	Virginia	2,000	800,461	125,092
	West Virginia	16,000	10,708,578	1,062,076
	Kentucky	10,000	1,245,785	48,619
	Tennessee	5,100	1,902,258	265,777
	Georgia	200	372,740	90,726
	Alabama	8,660	5,136,985	1,168,085
	Totals	64,390	81,207,168	9,011,862
Triassic.	Virginia	180	19,878	....
	North Carolina	2,700	17,000	....
	Totals	2,880	36,878	....
Carboniferous.	NORTHERN.—III.			
	Michigan	6,700	45,979	....
	CENTRAL.—IV.			
	Indiana	6,450	3,791,851	5,724
	Kentucky	4,000	1,761,394	....
	Illinois	36,800	19,949,564	2,200
	Totals	47,250	25,502,809	7,924
	WESTERN.—V.			
	Iowa	18,000	3,972,229	....
	Missouri	26,700	2,897,442	5,905
	Nebraska	3,200	2,652,546	8,565
	Kansas	17,000		
	Arkansas	9,100	574,763	....
	Indian Territory	20,000	1,252,110	7,135
Carboniferous to Tertiary.	Texas	4,500	302,206	....
	Totals	98,500	11,651,296	21,605
	ROCKY MOUNTAIN.—VI.			
	Dakota	Estimated 25,000	49,630	....
	Montana		892,309	29,945
	Idaho		....	....
	Wyoming		2,439,311	2,916
	Utah		413,205	....
	Colorado		4,018,793	362,986
	New Mexico		655,112	5,803
	Totals	25,000	8,468,360	401,650
	PACIFIC COAST.—VII.			
	Washington	Estimated 7,152	1,264,877	6,731
	Oregon		41,683	....
	California		72,603	....
	Totals	7,152	1,379,163	6,731
	Grand Totals	250,000	182,852,774	9,477,580

New York, from Penna. Coal	**12,850**
Wisconsin, from Connellsville Coal	**14,958**
	27,808

Value of Coal **$208,438,696**

Value of Coke **16,523,714**

Total Value of Coal and Coke, 1893 .... **$224,962,410**

CANADA.

In the Dominion of Canada, the coal deposits have been classed in three sections.

I.—The Nova Scotia and New Brunswick fields lying on the Bay of Fundy. They have a desirable location for marketing their coal on the Atlantic seaboard. The coal is similar in quality to the coal of the eastern Appalachian field. The coal measures are 13,000 feet thick. The aggregate area of these two fields is reported to be 18,000 square miles.

The coal belongs to the Carboniferous period, and is used for coking, for iron manufacture, and for all industrial and domestic purposes.

AVERAGE ANALYSES OF THEIR COALS.

	Pictou.	Joggins.	Springhill.	Nova Scotia.	Cape Breton.	Albertite.
Moisture	1.20	1.30	1.10	1.15	1.10	0.50
Volatile Matter	28.43	37.50	29.10	25.61	25.83	57.10
Fixed Carbon	56.98	56.00	56.60	60.73	67.57	42.40
Ash	13.39	5.20	13.20	12.51	5.50	0.27
Sulphur	....	....	....	....	....	....

II.—British Columbia and Vancouver's Island. The coal measures in this section belong to the Cretaceous and Tertiary formations. The coal beds are large and the quality is mainly of the better class of such coals. The amount of pressure appears to be the important factor in determining the physical properties of these coals, and consequently of their value.

ANALYSES BRITISH COLUMBIA AND VANCOUVER.

	a.	b.	c.	McKay. No. 14.	Nanaimo.
Moisture	15.75	8.60	36.065	4.01	1.70
Volatile Matter	35.40	35.51		40.07	38.10
Fixed Carbon	41.45	46.84	61.29	51.82	48.48
Ash	7.40	9.05	2.645	4.10	11.72
Sulphur	....	....	....	....	....

a, b, non-coking ; c, makes good coke.

III.—In the great plains, east of the Rocky Mountains, and in the eastern flanking ridges, the coal occurs in the Cretaceous formation, including the Laramie.

This field is simply the extension, northwards, of the lignite and brown coal measures of the Rocky Mountain series of the United States.

Some of these coals can be used for the manufacture of coke, but the larger proportion goes to other uses.

AVERAGE ANALYSES OF THE CANADA GREAT PLAIN COALS.

	a.	b.	c.	d.	e.
Moisture	20.54	10.85	6.50	4.41	0.71
Volatile Matter	33.26	34.40	38.04	40.32	10.79
Fixed Carbon	41.15	39.61	47.91	48 27	80.93
Ash	5.05	15.64	7.55	7.00	7.57
Sulphur	....	....	....	....	....

a, b, c, will not coke; d, makes good coke; e, Western anthracite.

The Mexican coals are evidently found in the Cretaceous or Tertiary formations, probably in the former. They appear to be related in part to the Texas coals.

The Coahuila Coal Company, near Sabinas, on the Mexican International Railroad, mine coal and make a fair quality of coke from washed Alamo coal. The analyses are as follows:

	Coal.	Coke.
Volatile Matter and Moisture	20.35	1.35
Fixed Carbon	67.64	83.80
Ash	12.01	14.85
Sulphur	0.86	1.08

This coke is used mainly in smelting establishments, and commands a ready sale.

It is a fairly good coke, approximating in its physical properties the Tioga coke of Pennsylvania.

The coal from which it is made requires careful and intelligent work in preparing it for the coke oven.

CHAPTER II.

THE PHYSICAL AND CHEMICAL PROPERTIES OF COAL.

Genesis of Coal in Vegetable Matter.—Flora Grew in Extended Swamps.—Covered with Sediments, Slates, Shales, etc.—Crystalized Under Great Pressure.—Atmosphere of the Coal Periods.—Time Required to Grow Vegetable Matter for Coal Beds.—Crust Movements in Producing Useful Beds of Coal.—A Variety of Coals from Different Conditions.—Ash in Coal, Minimum, Maximum.—Sulphur and Pyrites.—Bituminous Coal the Normal Condition.—Diagram Illustrating the Residual and Evolved Products of Vegetable Matter.—Cellulose, Graphite.—Changes, Chemical Formulæ.—Composition of Wood.—Table of Elements Composing Cellulose and Coal.—Progress of Plant Tissue to Coal.—Metamorphism, Traps, Dykes.—Debituminization of Coal Eastward.—Attributed to the Evolution of Heat from Flexure.—Western Coals in Normal Condition.—Table Showing Debituminization Eastward.—Section Showing Best Coking Coals Eastward.—Similar Qualities of Coal Beds in Common Zones.—Not Determined Why One Coal Will Coke and Another Will Not.—Coking Properties of Coals.—Composition of Coking Coals.—Review of the Several Qualities.—The Fusing Element or Elements in Coal.—Progress in Ascertaining These.—*American Manufacturer's* Article on the Fusibility of Coals.—Mr. Richard Thomas' Paper on Coke.—Why Coal Will Fuse.—Table of Analyses of Welsh Coals.—Ratio of Coking Coals, Hydrogen to Fixed Carbon.—General Considerations.—Exact Relations of Fusing Elements Not Definitely Established.—To Test Coal for Coking Use in Coke Ovens.—Connellsville Coking Coal.—Volatile Matter in Coking Coals.—West Virginia Coals.—Coking Coals Rich in Bituminous Matter.—Rocky Mountain and Pacific Coals.—Coking Different Varieties of These Coals.—Impurities in Coals.—Ash.—Sulphur.—Phosphorus.—Table Showing Percentage of Sulphur Expelled in Coking.—Table Showing Phosphorus in Coal and Coke.—General Conclusions.

The genesis of coal has been clearly shown to have been in the swamp flora of the old-time periods of coal making.

The vegetable origin of coal is therefore no longer questioned. This conclusion has been reached by the evidences of the remains of plants of these carboniferous periods, in immediate connection with the coal beds; by the physical structure of the coal disclosing the anatomy of the several families of plants from which it was made, and from chemical analyses tracing its derivation from vegetable matter.

Coal, therefore, was made from vegetable and woody matter, which grew luxuriantly in broad and extended marshes in the old age times of this continent. This vegetable matter, in its decay and fall, was entombed in the waters of these swamps, and was thus preserved from oxidation or

waste by excluding it from the atmosphere. This was followed by coverings of slates, shales, sandstones and limestone deposits, which afforded different degrees of pressure, in the entombing of the vegetable matter, and in the subsequent crystallization of the coal.

The flora of the coal making periods consisted mainly of the large families of tree ferns, siggillaria, calamites and their allies—soft, rapid-growing plants, with jointed stems and broad spear-shaped leaves, which fell in frequent showers into the waters of these marshes. These with the mosses, ground ferns and other plants, composed the vegetable mass that made the coal.

The atmosphere of the coal flora periods was in large part composed of carbon dioxide, which contributed largely to the heat and plant food of these times of the luxuriant growth of its flora.

But complementary to all these conditions of climate, rapid vegetable growth and swamp lagoons to preserve it for coal making, other great movements in the earth crust were of prime necessity in affording definite time for the accumulation of vegetable matter to make coal beds of useful thickness and to entomb them for the use of the coming age of man.

The broad geological law has been fully established, that all continents have been formed beneath the sea and then emerged from it. Not only this, but also from the way the several sedimentary formations rest upon each other, it is evident that the land has been emerged and submerged, alternately, many times in the processes of its formation.

The movements, therefore, of the submergence and emergence, in the times of the formation of the coal measures, are in entire harmony with the laws governing the formation of all the sedimentary deposits.

It will also be readily understood, that in the coal making periods, under varied conditions and extended time, a variety of coals have been made, with different degrees of purity, and inheriting varied relations of the ratio of fixed to volatile matters; especially in the subsequent movements in flexing the strata, producing the debituminization of the coal in greater or less degrees.

It is well known that all vegetable tissue contains some incombustible matter, which is designated as "ash" in coal. It ranges from one or two per cent., to five, ten or more, per cent., in the usual varieties of coals. When coal contains more than five per cent. of ash, it is evidence of the deposit of mud from other sources than the vegetable matter making the coal. This additional impurity has come into the coal from sediment in the waters of the marshes and from the fine muds composing the roof of the coal bed. The ratio of this fine mud or slate impurity in coal can increase until the former predominates, causing the product to lose its rank amongst the useful family of coals.

The usual law, with some exceptions, is, that this slate impurity in coal carries with it iron pyrites, FeS_2—a mixture of sulphur and iron—so that

the volumes of these undesirable impurities are usually found in a varying proportion to the amount of ash in the coal, increasing generally as the ash increases. But there are exceptions to this case.

It is assumed that what is now ranked as bituminous coal, represents the normal condition of all true coal, prior to the subsequent changes by the agencies of heat.

The accompanying diagram, Fig. 1, illustrates, in a general way, the chemical and physical changes in the formation of the several varieties of coal, from its organic constituents in plant tissue to the last result in graphitic carbon.

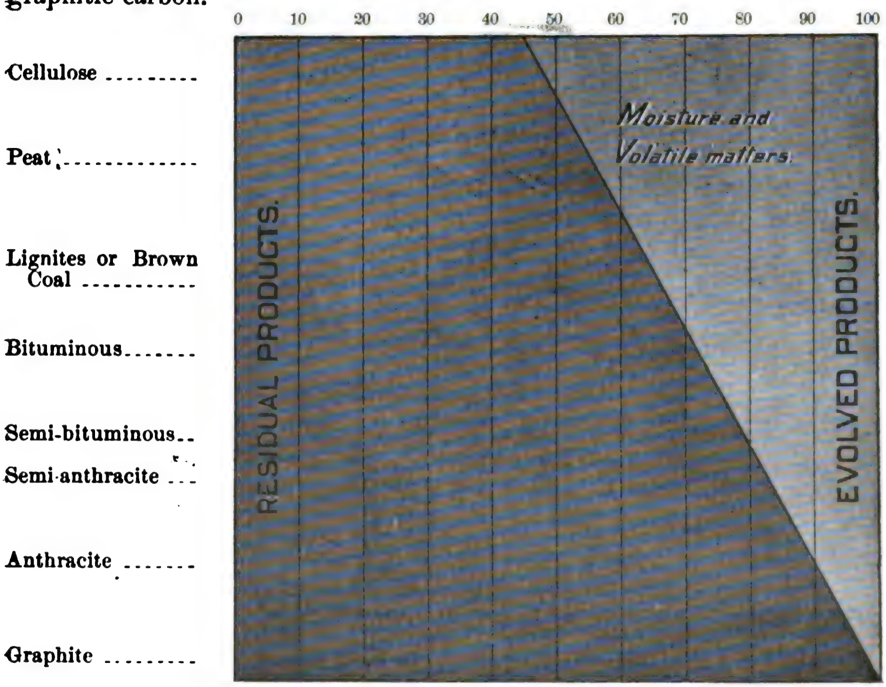


FIG. 1.
DIAGRAM SHOWING GENETIC RELATIONS OF THE CARBON MINERALS. AFTER PROF. J. S. NEWBERRY.

Professor Joseph Le Conte has given the approximate composition of these typical varieties of bituminous coal and graphite, and has constructed the following chemical formulæ showing the changes under which they were formed:

Vegetable Matter—Cellulose .... $C_{36}H_{60}O_{30}$*

$$\text{Subtract}\left\{\begin{array}{l} 9\ CO_2 \\ 3\ CH_4 \\ 11\ HO_2 \end{array}\right\} \ldots\ldots\ldots\ldots \; C_{12}H_{34}O_{29}$$

And there remain .... $C_{24}H_{26}O$=Cannel.

* The composition of *wood-timber*—is usually given as about $C_{12}H_{18}O_{8}$. I have taken the formula o cellulose instead, viz., $C_6H_{10}O_5$; or, taking six equivalents for convenience of calculation, $C_{36}H_{60}O_{30}$. I

Again, Vegetable Matter.............................. $C_{36}H_{60}O_{30}$

Subtract $\left\{\begin{array}{l} 7\ CO_2 \\ 3\ CH_4 \\ 14\ H_2O \end{array}\right\}$ .... $C_{10}H_{40}O_{28}$

And there remain.................................. $C_{26}H_{20}O_2$=Bituminous Coal.

Again, Vegetable Matter.............................. $C_{36}H_{60}O_{30}$

Subtract $\left\{\begin{array}{l} 10\ CO_2 \\ 10\ CH_4 \\ 10\ H_2O \end{array}\right\}$ .... $C_{20}H_{60}O_{30}$

And there remains.................................. C_{16}=Graphite.

The following table exhibits the principal elements of the genesis and varieties of coals.

Names.	Moisture.	Vol. Matter.	Fixed Carbon.	Ash.	Sulphur.	Phos.
Cellulose	....	55.36	41.44	3.00	0.20	....
Peat	24.20	27.00	45.30	3.30	0.20	....
Lignite	....	27.90	66.09	4.00	1.00	....
Brown Coal	....	29.06	66.31	2.27	2.36	....
Cannel "	2.10	14.99	68.13	12.30	2.48	....
Albertite "	....	13.86	86.04	0.10	trace	....
Bituminous	1.78	35.36	58.29	3.89	0.68	trace
Semi-bituminous	1.20	23.89	67.56	6.69	0.66	0.005
Semi-anthracite	2.27	8.83	78.83	9.39	0.68	....
Anthracite	2.98	3.38	87.13	5.86	0.65	....
Graphite	....	....	99.00	1.00	....	....

From the above will be noted the gradual changes effected during the lapse of time, in which plant tissue has been subjected to natural distillation. In the Western coal fields we have impressive examples of such changes, in the localities of trap outbursts, altering the Cretaceous or Tertiary coals to good bituminous and anthracite varieties. To what extent this metamorphism has affected many localities of far Western coals that

believe this to be much nearer the composition of the vegetable matter of the *coal period* than is the formula of hard wood like oak or beech. All the results may be worked out, however, with equal ease by the use of either formula for vegetable matter.

are now profitably used in the manufacture of coke, is not clearly made out. It is submitted by some observers, that the chief element is the *pressure*, from upheaval and flexure, that has altered these Western coals into the many varying grades in which they are found to exist.

It will be noted, however, that the evident cause of these changes in the varieties of coals, in the neighborhood of trap dykes or outbursts, with their resultant *heat*, is easily understood. But in large areas of coal deposits, without any evidence of eruptive heat, the cause must be sought in other conditions.

The rich bituminous coals of western Pennsylvania, the semi-bituminous coals on the eastern flank of the Alleghany field, the pure glassy anthracite of the eastern fields and the graphitic anthracite of the State of Rhode Island all belong to the same age—the true Carboniferous period.

From the analyses of these coals, it will readily appear that the largest evolved products of natural distillation occurred in Rhode Island, moderating in its action, westwardly, until the normal condition of bituminous coal is found in western Pennsylvania and Ohio.

And whilst there may exist some conflict of opinion as to the cause of this debituminization of coal eastward, the fact that such has been consummated is not in dispute.

In considering the cause or causes which have produced the various qualities of coals, the fact is quite evident, that all the anthracites in Rhode Island and in eastern Pennsylvania are found in sections *that have been violently flexed and tilted.* This work of folding and flexing the eastern flank of the continent must have been accompanied with a large amount of evolved heat, as the pushing forces exerted must have been enormous. As all the measures in these sections have been baked with heat in about the proportion of the violence of the disturbance in each locality, it is evident that the cause or causes have been as extensive as the results. Hence, it has been inferred, that the heat evolved in the flexing of the measures, combined with moisture and pressure, have been the chief agents in producing the conditions which have made the several varieties of coals.

As the coal beds westward reach quiet measures, the normal condition of bituminous coal is found intact.

This general law of the bituminization of coal westward has some slight exceptions. At the summit of the Alleghany Mountain, at Bennington, the coal contains 23 per cent. of volatile matter, whilst at Johnstown, 26 miles westward, it contains less than 20 per cent. of hydrogenous matter.

From Johnstown, westward, the increase of volatile matter is quite regular until the maximum belt of the normal bituminous coal is reached in western Pennsylvania and Ohio.

The coals of the eastern anthracite fields have been thoroughly coked under immense pressure, making this natural coke too dense for the best results in blast furnace operations.

This undesirable physical condition of extreme density will be fully considered hereafter.

The manufacturer of coke can, therefore, intelligently consider the qualities of the coals in the Appalachian and Western fields for use in making coke.

The following table gives the elementary composition of the typical varieties of coals, from Rhode Island to Iowa.

TABLE EXHIBITING THE DEBITUMINIZATION OF COALS—EASTWARD.

	Iowa.	Illinois.	Indiana.	Ohio.	Pennsylvania.				Maryland.	Penna.		Rhode Island.
					Pittsburgh	Connelsville.	Johnstown.	Bennington.	Cumberland	Semi-Anthracite.	Anthracite.	Graphitic Anthracite.
Moisture	1.40	1.25	1.10	2.70	1.28	1.26	1.03	1 20	0.89	1.25	1.35	1.18
Volatile Matter...	41.40	41.85	37.06	33.49	38.10	31.79	16.49	23.33	15.52	9.60	3.45	3.80
Fixed Carbon....	48.50	48.90	57 59	56.90	54.39	59.79	73.84	69.02	74.29	81.30	89.06	85.70
Ash....	7.50	7.00	3.50	5.99	5.44	7.16	7.97	5.69	8.59	6.90	5.81	8 52
Sulphur	1.20	1.00	0.75	0.92	0.79	0.60	1.97	0.76	0.71	0.85	0.30	0.80

It is also of interest to consider the irregular curved lines of the eastern escarpment of the great Appalachian coal field; with the deeply curved indents in Pennsylvania and Tennessee, displaying the immense forces that have flexed and pushed back bodily, these portions of the field.

In the subsequent erosion, Tennessee and Alabama suffered most, having had the dryer sections of their coals carried away and leaving the more western sections, with their increased volumes of volatile matter, for the manufacture of coke.

It has been noted that in these meridional sections of this coal field, if not in all fields, the qualities of the coal in the several beds approximate very closely in their chemical composition; so that if a good coking coal is found in any of the beds in a special section, all of its associated beds, above or beneath, will afford similar good results in coking.

And, whilst it is not yet clearly determined why one coal will fuse in the coke oven and make good coke, and another of very similar chemical composition will not fuse in the coking, yet in the Appalachian field it has been found reasonably sure, that coals of approximately equal chemical composition, will afford similar results in the process of coking.

The following analyses will show the composition of the standard typical coking coals in the Appalachian field:

	Pennsylvania.		West Virginia.		Kentucky.	Tennessee.	Alabama.
	Bennington.	Connellsville.	Monongah.	Pocahontas.			
Moisture......	1.78	1.26	1.52	0 69	1.80	1.50	1.65
Volatile Matter.........	23.89	31.79	37.96	19.96	32.84	32.51	32.48
Fixed Carbon.....	67.08	59.79	58.27	73.02	60.10	59.33	60.15
Ash........	6.69	7.16	6.08	5.67	5.10	5.82	4.82
Sulphur.............. .	0.66	0.60	1.22	0.66	0.66	0.84	0.90

The following shows the average composition of the celebrated Durham coking coal, England:

Moisture	0.90
Volatile Matter....................................	13.00
Fixed Carbon	80.80
Ash	4.39
Sulphur	0.91

It is very remarkable that this Durham coal, with its very low volume of volatile matters, fuses so thoroughly in the coke oven (Bee Hive) and produces first-class coke.

Such a well determined result adds to the perplexity of the investigation, in order to determine the reason "why one coal will coke and another will not."

THE COMPOSITION OF COKING COALS.

It may be interesting to compare the composition of some coking and non-coking coals from the Carboniferous measures and from the Jura-Cretaceous deposits:

TABULATED EXHIBIT OF COKING AND NON-COKING COALS.

State.	Locality.	Geological Formation.		Chemical Composition of Coals.						Remarks.
				Moisture 212° F.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.	Phos	
Pennsylvania...	Connellsville	Upper XIV.	a	1.25	31.80	59.79	7.16	0.53	0.024	Best Coking Coal
Virginias	Pocahontas	Lower XIV.	b	1.011	18.812	72.708	5.191	0.787		Best Coking Coal
Pennsylvania...	Broad Top	Lower XIV.	c	1.28	18.40	71.12	7.50	1 70	Trace	Good Coking Coal
Pennsylvania...	Bennington	Lower XIV.	c	1.20	23.68	68.77	5.73	0.62	0.017	Good Coking Coal
Pennsylvania...	Johnstown	Lower XIV.	a	0.72	16.49	73.84	7.97	1.97		Dry Coking Coal
Pennsylvania...	Greensburg	Upper XIV.	b	1.02	33.50	61.34	3.28	0.86		Good Coking Coal
Pennsylvania...	Armstrong Co.	Lower XIV.	b	0.96	38 20	52.03	5.14	3.66		Pitchy Coking Coal
Illinois.........	Mt. Carbon	Lower XIV.	c	2.08	38.20	53.47	8.02	0 63	0.027	Pitchy Coking Coal
Colorado........	El Moro	Cretaceous	d	0.95	29.82	56.41	12.82	0.41		Good Coking Coal
Colorado........	Crested Butte	Cretaceous	d	0.72	23.44	71.91	3.93	0.36		Good Coking Coal
Montana.	Sand Coulee	Cretaceous	c	2.26	33.60	54.47	7.82	1.85	0.009	Non-Coking Coal
Montana........	Belt Mountain	Cretaceous	c	2.98	28.71	53.31	13 34	1.65	0.012	Non-Coking Coal
Mexico.........	Coahuila Coal Co.	?	a	1.60	15.00	67.64	12 01	0.86		Coking Coal

The table exhibits the increase in the bituminization of the Appalachian coals westward. The experience of the past few years in coking these coals affords assurance that their coking properties can be estimated with a good degree of confidence, by the ratio of volatile hydro-carbons to the fixed carbon.

Pennsylvania, the Virginias, Kentucky, Tennessee and Alabama have been especially favored by large areas of good coking coals in this great field of 65,000 square miles.

The eastern side of it affords the coking coals best adapted for making metallurgical coke. The western side inherits too much bituminous matter to assure very good coke.

This law is shown in the pitchy coals of Ohio, Indiana and Illinois, by the small amount of coke made in these states.

The coals of Colorado, Wyoming, Montana and other north-western states, belong to the Jura-trias and Laramie Cretaceous measures, and are independent of the Appalachian law of ratio of volatile hydro-carbons to fixed carbon, as some of these coals can be coked readily in the common Bee-Hive coke oven, as at the Trinidad or El Moro, the Crested Butte and other coking works of Colorado, the Cambria Mining Company of Wyoming and the Bozeman and Gardner coke works of Montana.

On the other hand, a large portion of these north-western coals very high in hydrogenous matters *cannot be coked.*

It is slowly becoming evident, that the solution of the coking or non-coking properties of coals is entirely confined to the relations and volumes of the elements composing the *volatile combustible matters* of the coal.

The moisture, fixed carbon, ash and sulphur may differ widely in good coking coals, without seriously affecting their coking properties.

An example of this is seen in the very large difference existing in the volumes of carbon and ash in two of the best known coking coals, Connellsville and Pocahontas; the former containing 59.79 per cent. of fixed carbon and the latter 72.70 per cent. of this element. The ash is neutral, exerting no influence in the fusing of coal in coking. The sulphur and phosphorus come under the same condition—they are simply undesirable elements in metallurgical coke.

It will also be evident, that large differences exist in the volumes of the volatile combustible matters in the coking coals of the Carboniferous age in the Appalachian field.

From the percentages of volatile combustible matters in these coals, their relative coking properties can be confidently predicted.

These range in ordinary coke ovens from 17 to 33 per cent.; with retort ovens and their recuperative and regenerative auxiliaries, coals inheriting much lower percentages of volatile combustible matters can be coked.

The only further remark in this connection is, that in coking coals with small volumes of volatile combustible matters affording insufficient heat for

coking, the balance of the heat required must come from the *fixed carbon* of the coal.

As a unit of carbon affords about 8,000 calories of heat, whilst a unit of hydrogen affords 34,000 calories, it will readily appear that coals low in hydrogenous matters must surrender, in the ordinary open ovens, an increased volume of fixed carbon to compensate for the deficiency in the reduction of the greater heat giving hydrogen.

An example is seen in the loss of carbon in coking the Connellsville and Pocahontas coals in Bee-Hive ovens; the loss of the former is about 8 per cent., whilst the loss of the latter is about 20 per cent.

This large loss of carbon in the open coke ovens, especially in coking the "dry" coals, was evidently the impelling element in the evolution of coke ovens, in developing the *retort* or closed ovens with their auxillary recuperative and regenerative appliances, and in the utilization of the gases from the coking coal in heating the oven chamber and saving the fixed carbon in coking.

To assure sustained heat, as well as from the peculiar construction and length of these retort coke ovens, the charges of coke require to be drawn by mechanical appliances.

Returning to the evidence submitted, *locating* the *fusing* element or elements in coals of the Appalachian age, in their volatile combustible matters, it was shown that wide differences in the volumes of fixed carbon could exist in these coals, producing, as far as is now known, only slight modifications in their coking qualities.

But in the Jura-trias and Laramie Cretaceous coals, this Appalachian law will not, as a general principle, be found reliable. This will be seen in the efforts to coke the large samples of the Sand Coulee and Belt Mountain coals of Montana. In comparing their volumes of volatile combustible matters with the Connellsville, their close relations will appear as follows:

Connellsville, Pa....31.80 per cent. vol. comb. matters.
Sand Coulee, Mon...33.60 per cent. vol. comb. matters.
Belt Mt., Mon.......28.71 per cent. vol. comb. matters.

Connellsville coal is the standard coking coal of the United States, as far as present knowledge has disclosed; the coals of Sand Coulee and Belt Mountain cannot be coked.

On the other side, the Trinidad, El Moro coal of Colorado, located in the Cretaceous measures, and holding 29.82 per cent. of volatile combustible matters, affords a very good coke in Bee-Hive coke ovens.

This important inquiry, as to the composition of coals that will fuse in the coke oven, has elicited and continues to invite much earnest investigation from chemists.

And, whilst some approaches have been made in ascertaining the element or elements that produce fusion of the coal in coking, yet these are not fully assured as general principles that can be relied upon for universal application.

It is reported that some German chemists have made tests to ascertain the cause of the coking or fusing of bituminous coal in the coke oven, under distilling heat; the conclusion being that the fusing property of the coal is produced by its richness in what is known as "disposable hydrogen," or that portion which is in excess of the quantity required to form water with the oxygen present. It has been shown that such a standard for the fusing quality of coal does not correspond with observed results. So that we have in this no sure ground for this determination.

The richness of the coal in carbon does not appear to govern its fusing capabilities, the fact being that two samples of coal of practically equal carbon composition will be found to behave very differently in coking in the ovens.

It is evident that if the genesis of fusing does not reside in the surplus hydrogen or fixed carbon, it certainly does not lie in the oxygen, as the latter affords no indication of the physical behavior of coal in the retort of the coke oven.

The following extract on the fusibility and coking property of coals is taken from the *American Manufacturer*,—the author's name not being given:

"It has long been known that the property of coking which belongs to many coals—a property which may be observed in every degree, i. e., from a weak slagging to a complete fusion—is not a simple or partial fusion, and the fusion of mineral coal is accompanied rather by a fundamental decomposition of the same, just as is the case when sugar is subjected to a high heat, whereby are generated gases and vapors burning with a more or less luminous flame and leaving behind them a fused residue consisting chiefly of carbon.

"The very natural supposition that the fusibility or infusibility of a coal must always stand in fixed ratio to its proportional composition is not at all borne out by practice, although a number of isolated cases may seem to give it support.

"Percy (Metallurgy) found the following percentages of hydrogen, oxygen and nitrogen in several coking and non-coking coals:

	Non-coking.		Coking.			Non-coking.			
	1.	2.	3.	4.	5.	6.	7.	8.	9.
H......	4.75	4.95	5.49	5.85	5.91	6.34	6.12	6.04	5.99
O. & N.	5.28	7.36	10.86	14.52	18.07	21.15	21.13	22.15	23.42

"The following 'excesses' of hydrogen, over what was considered necessary to combine with the oxygen to form water, were found, that is, the remaining quantities of 'disposable' hydrogen:

	Non-coking.		Coking.			Non-coking.			
	1.	2.	3.	4.	5.	6.	7.	8.	9.
H......	4.09	3.53	4.13	4.04	3.65	3.70	3.47	3.22	3.06

"The property of coking evidently cannot depend on this 'disposable' hydrogen, since, for instance, in Nos. 1 and 4, non-coking and coking coals respectively, it is very nearly the same.

The sum of hydrogen and oxygen in these nine coals is:

10.03 11.81 | 16.35 20.37 23.98 | 27.49 27.35 28.59 29.41

"From this it might be inferred that a content of 7–18 per cent. of oxygen entails the property of coking. The following results, obtained from the experiments of W. Stein and of the author, however, are totally against such an inference:

		Coals free of Ash.			Hydrogen per 1,000 parts of carbon.			Coke.	Character of the Residue
		C.	H.	O + N.	Disposable.	Combined.	Total.		
Saxony	Oberhohendorf	83.28	4.55	12.17	36.38	18.25	54.63	67.70	Caked.
	Zwickau	83.82	4.19	11.98	32.09	17.90	49.99	69.95	Sandy.
	Zwickau	81.47	4.38	14.06	32.28	21.56	53.84	54.64	Caked.
	Niederwurschnitz	81.17	4.67	14.15	35.71	21.80	57.51	69.73	Crumbling coke.
	Niederwurschnitz	84.36	4.30	11.34	34.25	16.71	50.96	62.00	Coke weakly "fritted."
	Planitz	84.84	4.63	10.97	38.42	16.14	54.56	63.89	Caked.
	Niederwurschnitz	82.34	4.73	12.93	37.68	19.62	57.30	66.43	Sandy.
	Zwickau	82.59	4.76	12.65	38.50	19.13	57.63	77.29	Caked.
	Zwickau	78.71	4.27	17.02	27.30	26.93	54.23	77.44	Caked.
	Niederwurschnitz	78.71	4.51	16.75	30.73	26.54	57.27	60.81	Crumbling coke.
Westphalia	Pluto Mine, cannel coal	86.04	5.73	8.23	54.67	11.96	66.63	61.48	"Slagged" (gesintert).
	Mont Cenis mine, coking flame coal	84.89	5.72	9.39	53.66	13.80	67.46	64.29	Caked.
	Pluto mine, gas coal	83.17	5.37	11.46	47.41	17.21	64.61	66.86	Caked.
	Pluto mine, gas coal	83.16	5.42	11.42	47.95	17.17	65.12	68.28	"Slagged."
	Alma mine	87.47	5.03	7.50	46.74	10.71	57.45	75.80	Partially "slagged."
	Prasident mine	87.79	4.97	7.24	46.36	10.30	56.66	77.60	Caked and much swollen

"Of the Saxon coals, for instance, Nos. 7 and 8, as well as Nos. 9 and 10, while having a very similar composition, show entirely different results by the coking test. The same is true of each pair of the Wesphalian coals analyzed.

"For single coal fields it is, of course, possible to establish some limits. Richter, for instance, has done this for the coals of lower Silesia, though only in an introductory way:

'*a.* So-called coking coals contain, with few exceptions, 40 parts of "disposable" hydrogen per 1000 of carbon.

'*b.* In case of equal content of "disposable" hydrogen, the coking power increases the more the combined hydrogen falls below 20 per mille of carbon. Coals of 20 per mille content of combined hydrogen, and even those of 17 to 18 per mille do not, in lower Silesia, belong to the number of cok ing coals, properly speaking.

'*c*. Although the above may be accepted as the rule, it must still be noted that sometimes coals of almost the same composition show very different coking properties.'

"A sort of rule may be deduced as follows, from the analyses of several hundred Westphalian coals:

1. Coking coals (swelling in the process of fusion) contain, per 1000 of carbon, over 40 of 'disposable' hydrogen and 10 of combined hydrogen, or under 40 of 'disposable' hydrogen and over 9 of combined hydrogen.

2. Open-burning or 'slagging' coals (that is, fusing, but not swelling) contain, per mille of carbon, over 34 of 'disposable' hydrogen and over 9 of combined.

3. Close-burning coals contain, per mille of carbon, under 40 of 'disposable' hydrogen and under 9 of combined.

"The property of fusing or not fusing finally depends on the presence or absence of certain carbon compounds, of which intimate knowledge is probably not attainable."

Mr. Richard Thomas, in "A Paper on Coke," read before the Alabama Industrial and Scientific Society, submits a tabulated statement showing the ultimate composition of some Welsh coals, and from the coking or non-coking properties of these, infers that the fusing element in coals consists of the relations of the hydrogen to the carbon.

TABLE 1.—SHOWING COMPOSITION OF WELSH COAL.

No.	C.	H.	N.	O.	S.	Ash.
1	91.44	3.46	0.21	2.58	0.79	1.52—100
2	84.87	3.84	0.41	7.19	0.45	3.24—100
3	89.01	4.49	1.16	1.65	1.03	2.66—100
4	89.78	5.15	2.16	1.02	0.39	1.50—100
5	81.72	5.76	0.56	8.76	1.16	2 04—100
6	87.48	5.06	0.86	2.53	1.03	3.04—100
7	82.75	5.31	1.04	4.64	0.95	5.81—100

TABLE 2.—SHOWING AMOUNT OF COKE AND WHAT WAS VOLATILE.

No.	Coke.	H.	N.	O.	C.	Hydrogen to Carbon.
1	92.9	3.46	0.21	2.58	0.85—100	H. 1. C. 26.4 Anthracite.
2	85.5	3.84	0.41	7.19	3.06—100	H. 1. C. 22. 1 Semi-anthracite.
3	84.55	4.49	1.16	1.65	3.14—100	H. 1. C. 19.8 Bituminous.
4	77.5	5.15	2.16	1.02	14.18—100	H. 1. C. 17.4 "
5	68.4	5.70	0.56	8.76	16.58—100	H. 1. C. 16 "
6	72.94	5.06	0.86	2.53	18.61—100	H. 1. C. 17.1 "
7	67.10	5.31	1.04	4.64	21.91—100	H. 1. C. 15.6 "

He gives the following descriptions of the above coals:

"Coal No. 1—or Welsh Anthracite. This coal will not fuse, neither will the lump coke like the other coal. The analysis shows 92.9% of coke from the coal. In appearance, it is more like a drying up coal than coke. In place of cells, it looks more like cracks. By disintegrating the coal, and using about 6% of pitch, the latter being about 12 of hydrogen to 88 of carbon, the two combined make a very strong coke. The fracture did not show the cells the same as the coking coal, but was granulated in appearance. They claim that it worked well for foundry purposes and commanded a price from three to four shillings per ton more than the coke made in the same locality from the bituminous coal. The loss in volatile matter in this coal was very small. The difference in carbon from coal to coke was less than 1%. The analysis shows 3.46 of hydrogen, and 2.58 of oxygen. It seems by the proportion of volatile carbon to the amount of oxygen that the two had combined into carbonic oxide. Had the carbon and the hydrogen combined, it would have formed the light carbide of hydrogen, which is composed by weight of 75% of carbon to 25% hydrogen. In that case, there would have been a loss of over 10% of carbon. On the other hand, if the amount of oxygen had combined with the hydrogen, and formed water, the amount of hydrogen would not have exceeded 0.32 of 1%. It is very clear that the hydrogen, in the anthracite, must have escaped almost in a pure state from the coal, and mixed with the oxygen of the air and formed water.

"Coal No. 2—Has a little more hydrogen, and like No. 1 it will not fuse; neither will it coke, only when mixed with pitch, or some of the other solid volatile carbon. This coal would have to be treated the same as No. 1 to make coke. The coking of No. 1 was discontinued for a time, owing to the advance in the price of pitch, there being such a demand for the article to mix with the dry non-fusible coal, to make patent fuel.

"Coal No. 3—This coal is known, the world over, as the Aberdare and Merthyr Smokeless Steam Coal. This is 2.33 less in carbon than No. 1, but higher in hydrogen, by a little over 1% than No. 1. It has only 1.65 of oxygen, and it shows a loss of carbon in coking of 8.14, the oxygen being so low.

"The carbon, in this instance, must have formed gas, most likely the light carbide of hydrogen. This coal has not sufficient hydrogen and carbon to fuse, but the lumps make a good furnace coke and is used very extensively. The slack of No. 3 will coke when disintegrated with richer coal, being in proportion about half and half; or when the hydrogen would be about 5% in the coal—or, say, 1 of hydrogen to 17.5 carbon. The two combined will yield about 75% of coke from the coal.

"Coal No. 4—Will fuse and make a strong coke, and is a coking bituminous coal. I have noticed that whenever it gives say 75% of coke from the coal, the color of the coke is dark grey and shows the cells very clearly; but it will not have a smooth, silvery gloss on it. None of the dry coals have.

"Coal No. 5—This coal shows 8.06 less carbon than No. 4, but it has 7.74 more oxygen in it, and has also 0.61 more hydrogen. The hydrogen is 1 to 16 of carbon. This will make a bright coke of silvery appearance.

"Coal No. 6—Makes a good furnace coke, and shows the cells a little darker grey in color; the yield being rather high to be glossy.

"Coal No. 7—This coal cokes more like the Connellsville, of Pennsylvania, than any I have ever seen. This coke, in appearance, has a very smooth, silvery gloss, when cooled in the ovens. The best coke in this series is made from a vein called the Crepwr vein. It makes a good, strong furnace coke, and is largely used for foundry purposes. Owing to a slate roof, some of which falls in mining, the slack in some of the mines is washed, but the vein is free from all impurities, and averages about eight feet thick."

He concludes that No. 1 coal, with a proportion of hydrogen to carbon, of 1:26.4, will not fuse in the coke oven

No. 2 coal, with a proportion of 1:22.1, will not coke. No. 3, a smokeless steam coal, inheriting a proportion of hydrogen to carbon of 1:19.8 will not fuse readily. Nos. 4 to 7 embrace the fusing or coking coals. The best relation of hydrogen to carbon amongst these is found in No. 7, which is reported as producing a coke "more like the Connellsville."

This coal has a proportion of 1:15.6; hence it is inferred that coals inheriting ratios of hydrogen to carbon, as the series from 4 to 7 show, are good coking coals. It may be of interest to note that the Connellsville coking coal inherits relations of hydrogen to carbon, in its composition, of 1 to 14 nearly.

The Monongah coal of West Virginia contains the relations of hydrogen to carbon of 1 to 10.7. The celebrated Durham coking coal of England, has a proportion of 1 to 17.2.

All these coals fuse in a very thorough manner, making excellent metallurgical coke.

On the other side a readily fusing coal from Ohio, has its hydrogen to carbon as 1:9.8, which indicates a close relationship to the West Virginia variety.

In the Saxony and Westphalia coals, two samples of coal afford proportions of 1:17.4 and 1:17.6 respectively; the former made a crumbling coke, whilst the latter was "caked and much swollen."

These investigatious indicate progress, but do not go far enough in embracing the different varieties of coals with their varying conditions so as to enable the coke manufacturer to determine accurately from the ultimate analysis of his coal, whether it will fuse in the oven and make good metallurgical coke, or if it is a non-coking coal.

The relations of the elements in coal that produce fusion in coking, with the reasons therefor, are yet not fully determined. They invite further investigation.

In the interim, until the exact relations of the coking elements of coal are assuredly determined, it will be the safest course, in ascertaining the coking properties of the coal, to have a sufficient quantity of it tested in a coke oven.

This will settle the whole matter beyond any doubt.

The Connellsville coking coal is found, in the upper coal measures, at a certain distance from the eastern seaboard, to give its coal a special adaptability for the manufacture of coke.

It holds, practically, 32% of volatile matter. The bed is 8 to 10 feet thick. Its coal has a decided columnar structure. In mining, the coal crumbles into a finely divided condition, well adapted, without further preparation, for charging into the coke ovens.

The central West Virginia coals are much more bituminous than the Connellsville, the Monongah coal inheriting 38% of volatile matter, whilst the Pocahontas coal, in the southeastern side of this field, holds only 20% of volatile matters. These are the typical coking coals of these sections of the Appalachian field.

The Kentucky, Tennessee and Alabama coals approach, in percentage of volatile matters, to the Connellsville coal.

These coals make very good coke.

In the Central and Western fields the coals are quite rich in bituminous matters, and as yet they have not been distinguished in the manufacture of coke.

With our present inexperience of the best methods of treating these coals, in preparing them for coking and in the use of the oven best adapted for securing good coke, few attempts have been made in these respects.

It is evident that experimental work along these lines will, in the near future, become a necessity, especially in eliminating sulphur from these coals.

In the Rocky Mountain and Pacific Coast regions, no sure inferences can be drawn from the chemical composition of the coal, as to its coking properties. In one locality the coal cokes readily, making a good marketable coke; in another, the coal, with very similar composition, will not coke; if placed in a coke oven it will part with its volatile matter without fusing—the result will be *charred coal.*

The only sure method of determining the value of such coals for the manufacture of coke is, as before indicated, to have a quantity of it tested in a coke oven.

This will show its coking or non-coking properties without any doubt. A few dollars expended in this preliminary work will save in the end a great many.

The kind of coke oven for these special qualities of coal can be ascertained by consulting some reliable expert in coke oven plants.

The impurities in coals consist of ash, sulphur and phosphorus.

The ash is usually a negative element, having little chemical influence

in the use of coal and coke, unless it is mainly composed of silicious matter, in which case it will produce "clinkers," which are always undesirable.

Economically considered, in coke for blast furnace use, it not only displaces carbon, but requires increased charges of limestone and coke to dispose of it in the slag. Some qualification to this has been indicated in the smelting of the "dry" Lake Superior ores, that the ash in coke contributes somewhat to the formation of slag in the furnace—but ordinarily it is an expensive application.

The sulphur in the coal is usually found in three conditions—bisulphide of iron (FeS_2), "iron pyrites," sulphate of lime and "free sulphur," that is, sulphur not in combination with iron.

If sulphur is present in the coal united with lime, as sulphide of lime, a large portion of it will be volatilized in coking; but if it takes the form of sulphate of lime, gypsum, it will not be volatilized in a coke oven.

The following table shows the percentage of sulphur volatilized in coking:

NAME OF COAL.	Coal Bed.	Sulphur in Coal. — Per Cent.	Iron in Coal. — Per Cent.	Sulphur Required to Form Iron Pyrites. — (Fe S_2.)	"Free Sulphur" — Per Cent.	Per Centage of Sulphur not in Combination with Iron. — "Free Sulphur"	Sulphur Left in Coke.	Sulphur. — Per Cent. in Coke.	Sulphur Volatilized. — Per Cent.
L. Vernon's Coal	Pittsburgh	0.982	0.448	0.512	0.470	47.86	0.452	0.782	53.97
Danl. Miller's................	"	1.941	1.155	1.320	0.620	31.99	1.098	1.808	43 42
P. and B. Coal & Iron Co....	Rose	4.037	3.276	3.744	0.293	7.25	2.694	3.590	33.26
Sharpless and Kinkead	Lower Kittanning ..	0.956	0.448	0.512	0.444	46.44	0.492	0.840	48.53
Connellsville................	Pittsburgh.....	0.784	0.567	0.648	0 136	17.34	0.512	0.746	34.69
Diamond Gas Coal Co........	Bed D.........	1.118	0.812	0.928	0.190	16.99	0.683	1.070	38.90
Fairmont Coal Co	" ".........	1.960	1.673	1.912	0.048	2.45	0.960	1.470	51.02
Rockhill Iron & Coal Co.....	" G.........	2.483	1.960	2 240	0.243	9 78	1.676	2 008	32.50
Dennison, Porter & Co	" B.........	1.792	1.274	1.456	0.336	18.75	1.012	1 391	43.52
Morris Run Coal Co	" ".........	0.583	0.133	0.152	0.431	73.92	0.497	0.618	14 75
Fall Brook Coal Co..........	" ".........	0.661	0.133	0.152	0.409	61.87	0 561	0.696	15.12
Barclay Coal Co	" ".........	0.776	0.168	0.192	0.584	75 25	0.565	0.688	27.19
Miller's Coal (Tionesta)......	Mercer.........	1.951	0.721	0.824	1.127	57.76	0.821	1.620	57.92
Saltzburg Coal Co	Pittsburgh.....	2.257	1.267	1.448	0.809	35 84	1.305	2.057	42.18

The above table is from volume M. M. of the second geological survey of Pennsylvania, by Prof. Andrew S. McCreath.—Prof. McCreath adds: "Seven coals with an average of 63.51 per cent. of their sulphur existing as 'free sulphur' lost 34.57 per cent. of the sulphur by coking; on the other hand, eleven coals with an average of only 11.36 per cent. of sulphur not combined with iron, lost 37.88 per cent. Again, two coals with an average of 74.58 per cent. of the sulphur 'free' lost 20.97 per cent by coking; while two other coals with only 2.20 per cent. of the sulphur 'free' lost 44.81 per cent. In the presence of such results, therefore, it would seem to be impossible to accept the statement that all the 'free' sulphur passes off with the volatile matter in the process of coking.

"In the twenty-five coals examined the percentage of sulphur expelled by coking varies very much, the maximum amount being 57.92 per cent., and the minimum 14.75 per cent. The average percentage is 38.50; and the average percentage of 'free sulphur' is 33.79.

"Where, therefore, a careful handling and subsequent washing of the coal will not remove the excess of sulphur, it is scarcely to be hoped that this can be accomplished by the usual methods in the coke ovens. And this important consideration should be borne in mind when selecting coals for the manufacture of coke for use in blast furnace or foundry."

Phosphorus in the coal usually goes over to the coke. It is not eliminated in the coke oven. The following table of Pennsylvania coals affords some typical examples:

NAME OF COAL.	County.	Coal Bed.	Phosphorus. Per Cent. in Coal.	Phosphorus. Per Cent. in Coke.
Henderson's	Washington	Washington	0.1667	0.2818
Redds'	"	Pittsburgh	0.0943	0.1551
Penn. Gas Coal Co	Westmoreland	"	trace.	trace.
Millwood	"	"	0.0801	0.1177
Connellsville	Fayette	"	0.0111	0.0161
Cambria Iron Co	Cambria	B	trace.	trace.

The investigation of the volume of phosphorus contained in coals, suitable for the manufacture of coke for steel making purposes, discloses the fact that this volume of phosphorus varies from a mere trace to a maximum of 0.1248 per cent.

In the examination of twenty-four coals from the large Pittsburgh bed, the average was found to be 0.0217 per cent., which would give to the coke an average of 0.0344 per cent.

The great necessity of the utmost care in selecting coals for the manufacture of coke for metallurgical uses as free from the impurities of ash, sulphur and phosphorus as possible will readily appear.

It has been pointed out that an excess of ash in the coal is injurious to the perfect physical development of the coke, especially in its hardness of body.

The sulphur, when present in coke in large volume, confers on pig metal the undesirable property of "red-shortness." Coke for use in blast furnace work producing Bessemer pig, should not contain over 1% of sulphur, as a maximum volume. Coke containing 0.50% to 0.75% of this element would be much more desirable in the manufacture of pig iron for making steel. An undue volume of phosphorus produces an opposite quality in the metal made by it—the condition of "cold-shortness"—that is, metals made by coke containing an excess of these dangerous elements are found to be brittle in their hot and cold conditions. As none of the phosphorus in the coal is eliminated in the process of coking, it is of the utmost importance to select coals for the manufacture of coke for Bessemer uses, as low as possible in this dangerous impurity. The table on page 36 shows 0.0111% of phosphorus in the Connellsville coal.

Portions of the ash and sulphur can be removed from the coal for coke making by the processes of crushing and washing (see Chap. III.), but the phosphorus usually goes over in full to the coke and finally to the pig metal in blast furnace work.

CHAPTER III.

THE PREPARATION OF COALS FOR THE MANUFACTURE OF COKE.

Expansion of the Steel Industry.—Steel Replacing Iron.—Necessity of a Pure Fuel for the Manufacture of Steel.—Duty and Interest of Coke Manufacturers to supply a Clean Fuel.—The Area of the Best Coking Coals is Diminishing.—The Secondary Qualities of Coking Coals must come into use.—First Qualities of Coking Coals Require but Little Preparation for Coking.—Connellsville, Pocahontas, New River, West Virginia Coking Coals.—Breaking Coal Helpful in making Coke.—Dry Coals to be disintegrated.—Treatment in the Dry Way.—Washing if Needed.—Coal must be Classified if Washed.—Bradford Coal Disintegrator.—Coal Broken and Slate Separated in this Process.—Drawings of Bradford Cylinder Breaker.—Description of the Operations of the Bradford Breaker.—Large Plant at the Cambria Iron and Steel Works, Johnstown, Pa.—Cost of Plant and Cost of Breaking the Coal.—Stedman's Coal Breaker.—Stedman's Disintegrator.—Detailed Estimate of Cost and Work.—Breakers Useful in Preparing Coal for Mechanical Stokers.—Attention given to Preparing Coal for Coking in Europe.—The Sluice Washer.—Wasteful in Water.—Elliott's Improved Sluice Washer, Economizing Labor and Water.—Principles of the Improved Washers.—Pulsing Currents.—Slate Separated from Coal by its Difference in Specific Gravity.—The Hartz Jig: Description, Capacity, Cost of Operation.—The Bérard's Coal Washing Machine: Description, Cost, and Cost of Operating.—The Stutz Improved Coal Washers: Cost, Description, Operation, and Cost of Operating per Ton.—General Remarks on Principles of Separating Impurities from Coal.—Walter M. Stein's Washers: General Description, Cost, Work, Cost of Operating per Ton.—The Diescher Washer: Description, Operation.—The Walburn-Swenson Washer: Description, Analyses Exhibiting Cleansing Properties, Cost of Plant.—The Robinson Coal Washing Machine: Cost of Operation.—The Lührig Washer: General Principles.—The Dowlais Washing Arrangements.—English Washing Machinery.—No Excuse for Dirty Coke.—Great Necessity of Clean Coke for Metallurgical Purposes.—The Expense and Danger of Using Slaty Coke in Blast Furnaces.—The Safe Plan to Secure Clean Coal for Coke Making.—An Ample Supply of the Best Coals in America.—Coal Washing in Great Favor in Europe.—Only Necessary in America when Inferior Coals are used for Coking.

It is becoming quite manifest that we have reached a period, in the United States, in which steel is rapidly displacing iron in the arts, manufactures and structural uses.

This fact carries with it the increased necessity of a pure fuel in its manufacture.

It becomes, therefore, the duty as well as the interest of the coke manufacturer, to adopt such methods, in the preparation of coal for making coke, as will insure the purest and best possible product.

Large areas of the best coking coals require no special treatment, but are charged into the coke ovens as they come out of the mines.

In the Connellsville region, with a few exceptions, no preparatory work on the coal is attempted.

It is charged into the ovens as it comes from the mines. In mining this coal, it usually breaks up into small pieces. This follows from the softness of the coal and its attenuated columnar structure.

With the mining, handling into tipple bins and larries, it is broken into pieces sufficiently small to assure good results in coking.

A second type of this coal is found in the Flat Top region of Virginia. The coal is mined in more solid lumps than the Connellsville, but it is broken up, as the screenings are used in making coke.

The bituminous coals of the central and New River sections of West Virginia are usually broken and the screenings washed preparatory to coking.

The Alleghany Mountain coals are frequently charged into the ovens as they come out of the mine, but the best results are assured by breaking the coal or by breaking and washing.

From the experience gained in the use of these typical coking coals, the methods of treatment of representatives of these types will be apparent.

In practice it has also been discovered that breaking the coal that comes from the mine in large lumps, especially when the percentage of its volatile matter is small, adds to the value of its coke.

The importance of this disintegration of the coal before it is charged into the oven will readily appear, when it is understood that in this condition, other things being equal, the fusing elements, assumed to be in the volatile matter, are utilized to the utmost.

It has been found that a mixture of lumps and fine or small coal, low in volatile matter, fuses in the process of coking unevenly, the fine coal fusing rapidly in coking, whilst the lumps fail to fuse in a similar manner. It follows, therefore, that all coals, low in volatile fusing matter, will be benefited by being disintegrated before going into the coke oven, even if they do not require the further process of washing.

But when the slate is in large percentage, carrying in it sulphur as it usually does, in the condition of iron pyrites, the further process of washing becomes absolutely necessary.

In the selection of machinery for disintegrating or washing coal, or both, it will be wise to consult those experts in these processes who have made these practical operations special studies.

A general principle should govern in these matters, to insist on the application of the simplest machinery with the largest practicable automatic action.

Every variety of coal will require special apparatus for its treatment, which can only be determined by a careful study of the physical and chemical properties of the coal. All coal requiring washing should be carefully classified. This will insure the most efficient removal of slate or other impurities, as it will afford the best condition for their separation in the washer by the difference in their specific gravities; the coal of equal size being the lighter will rise, whilst the slates or pyrites, the heavier matter, will sink in the pulsing water of the washers.

Some coals have their slaty impurities so mixed with fireclay that they melt in the water in the washer.

Efforts have been made to treat these difficult coals in the dry way, by passing the classified products through a current of air, the separation being effected, just as in water, by the difference in the specific gravities of the coal and its impurities.

Other methods have been tried, with indifferent success. In the examination of the characters of coals requiring special and expensive appliances, with doubtful results, it will be well for the coke manufacturer to avoid the use of such coal.

For the disintegration of coals requiring this preparatory process, with the removal of slate and pyrites, the Bradford coal breaker will be found well adapted and economical.

It is simply a drum or cylinder of iron parts, having its lagging perforated to gauge the size to which it is desired to reduce the coal. This is accomplished by the percussion of the coal falling in the interior of the revolving drum from the upper to the lower sections.

The length of this fall, or the diameter of the drum, is made to meet the requirements of the coal.

If the coal is soft and friable, the length of the diameter is minimum; if the coal is hard and tenacious, the diameter of drum is increased accordingly.

The drum is fed with coal at one end, the slate and other refuse being discharged at the other end; the pure coal passes through the meshes in the lagging of the drum and is received into a pit from which it can be elevated to any desired level.

It is worthy of note that this method of disintegration, with separation of slates and pyrites, also removes "bony" coal, as the force of the fall in the drum is regulated to afford just sufficient concussion to break the purer portions of the coal, leaving the "bony" coal unbroken and discharging it with the other impurities.

The following drawings, Figs. 2 and 3 will exhibit the sectional plan of the Bradford patent coal breaker:

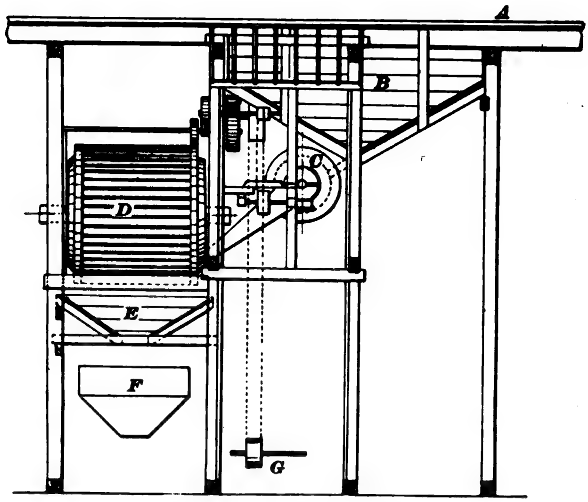


FIG. 2.—SIDE ELEVATION.

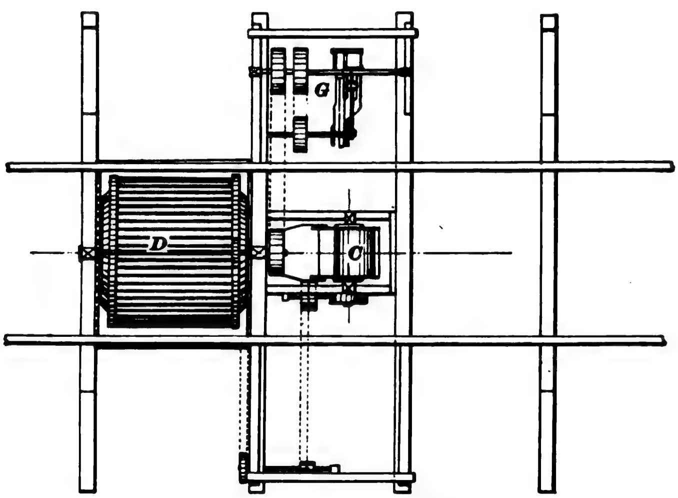


FIG. 3.—PLAN WITH BIN REMOVED.

The Bradford Patent Coal Breaker as put on the market at present, by Messrs. Heyl & Patterson of Pittsburgh, Pa., who control and build it, differs very materially from its original form, which consisted of a cylinder supported on stationary rollers; in this shape it was not found very satisfactory, but was operated long enough to demonstrate the value of the principles involved; the breaker as now constructed has trunnions cast on both heads, which carry the entire weight. The bearings are protected from the dust and are provided with thorough lubricating devices, thus reducing the amount of power consumed to a minimum.

Figure 2 is an elevation of the breaker showing the method of supporting it, also of the driving mechanism. The diameter of the breaker *D*

varies from 7 ft. to 12 ft., depending on the hardness of the coal; 9 ft. diameter being the general size used, the length varying with the results to be obtained. The heads with trunnions and spreaders are made of cast iron of proper proportions. The lagging or mesh, which consists of steel plates perforated with holes varying from $\frac{1}{2}''$ to $2\frac{1}{2}''$ square are securely fastened to the separators. To the plates are bolted cast iron fingers which aid in breaking the coal as it falls on them. To one of the heads is fastened a segment gear which engages in a pinion on the counter shaft placed on top of the bents supporting the breaker.

The coal passing into one end of the breaker under the trunnion, is picked up by longitudinal shelves and discharged, falling on perforated plates; that which is then of proper size passes through the mesh and the larger pieces are picked up by the next shelf and again thrown down. The coal, in falling from the shelf, has not only the force derived from its own gravity but receives a very considerable additional force from the momentum of the breaker. The fingers mentioned above not only aid in the breaking of the coal when it falls on them, but, being so designed as to form portions of spirals, can be regulated either to rapidly advance the body of the coal and impurities to the opposite end of the breaker or to retard its progress. Fastened in the opposite head of the breaker from that at which the coal enters are wings which discharge the substance that reaches them. The principle involved in the separation in this machine is that the slate and sulphur are usually harder than the coal and a fall sufficient to break the coal will not break them. The bony coal is usually harder and always very much tougher and will not break with the same fall or force as the coal. By varying the speed of the breaker the force of the fall can be increased or decreased and with the adjustment in fingers the impurities can be retained in the breaker until all the coal is freed from them. Pieces of iron, such as miners' wedges, couplings, etc., which frequently get among the coal and cause breakage in most machines for this work, will pass through the breaker and be discharged by the wings at the end without any damage, or injury to the machinery. The speed of the breakers never exceeds 20 revolutions per minute and they require but 7 H. P. when operated to full capacity. The capacity of the breaker varies from 300 to 700 tons per day according to the mesh, hardness of coal, and amount of impurities to be removed.

As it is necessary to have a regular supply of coal to the breakers to secure the best results, a cylinder feeder is used in connection with it. By reference to figures 2 and 3, the feeder *C* will be seen placed under the bin *B* and at the end of the breaker *D*. The feeder has two pockets, which as it rotates, are filled and discharged into the chute which leads to the breaker. This feeder will handle successfully the largest lump or run of mine coal, allowing the bin above it to be filled full. The feeder is not only valuable for regulating the supply of coal to the breaker but in plants

where the coal is handled, after leaving the breaker, in elevators or conveyors, it prevents the overloading of them. The coal is dumped from the tipple *A* into the bin *B*. From there it is fed into the breaker *D* by the feeder *C*. From the breaker it passes into the bin *E*, and is then loaded into the larry *F*.

The cost of a plant of one 9 ft. breaker such as illustrated by figures 2 and 3 and installing the same ready for operation, exclusive of boiler, does not exceed $3,000. A plant of this size requires very little attention and it is unusual for additional help to be employed, other than that required for handling the coal on the tipple.

There are now eight plants comprising twelve breakers in Western Pennsylvania and three plants in other States. The largest plant is that of the Rochester and Pittsburgh Coal and Iron Co. at Walston, Pa., where they have three breakers with a daily capacity of 1,200 tons through a ⅝″ mesh, and elevators for lifting coal to a vertical height of eighty feet and discharging it into a storage bin, as well as a conveyor for removing refuse; the expense for labor operating this plant does not exceed $2.50 per day.

The Vesta Coal Co., at Lucyville, Pa., is operating one 12 ft. diameter breaker with 1¼″ mesh which has a daily capacity of 750 tons. This plant, being situated in the fourth pool, Monongahela river, handles probably as hard a coal as is coked any place in the country. They do not employ any help except that necessary for the dumping of coal on tipple.

The arrangements for the Bradford coal breaker, in the works of the Cambria Iron Company, Johnstown, Pa., were designed by Mr. Joseph Morgan, Jr., Chief Engineer of that company. It is capable of breaking sixty tons of coal per hour.

Mr. M. G. Moore, the mining engineer, gives the following estimate of its cost:

Chute and screens in place	$228.00
Bradford breaker, with feeder, hopper, elevator, conveyors, belts, shafting and pulleys, in place	4,722.00
Engine pipes and fittings	1,126.60
Syphon and strainer	17.25
Foundations, bolts, &c., &c	1,729.51
Lumber	1,095.89
Labor, Masons, Carpenters, &c	2,882.91
Total	$11,802.16

In the work of breaking the coal, it is delivered into the feeder direct from the mine cars, without any additional expense. One man is required to run the little driving engine at $1.50 per day.

During a continuous run of seventeen days at this breaker, with the use of $3556\frac{7}{10}$ net tons of coal as it came out of the Rolling Mill Mine, 35½ net tons of slates and pyrites were removed in passing through this breaker, which shows a reduction of these impurities of one per cent., nearly.

Estimating the cost of engineer, oil, steam, &c., at $40 for these seventeen days of trial, it will be seen that the expenses of this work of breaking the coal is about 1¼ cents per net ton.

STEDMAN'S COAL BREAKER AND DISINTEGRATOR.

The Stedman Foundry and Machine Works of Aurora, Illinois, present two machines for the treatment of coal in preparing it for coking; the *Coal Breaking* and the *Coal Disintegrating* appliances.

THE COAL BREAKER.—The accompanying illustrations, figs. 4 and 5, will show the general operations of this machine.

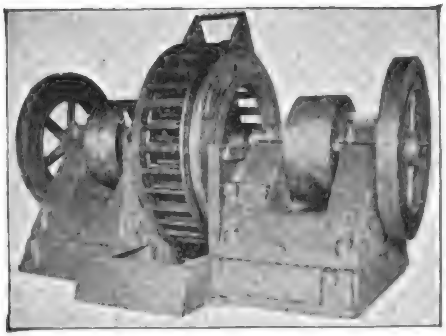


FIG. 4.—STEDMAN'S COAL BREAKER.

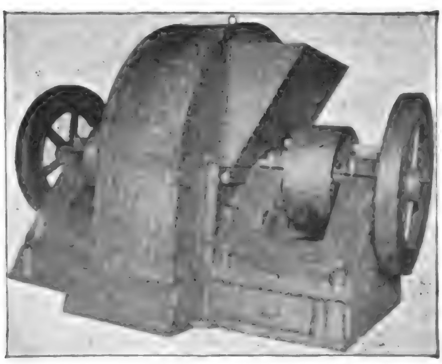


FIG. 5.—STEDMAN'S COAL BREAKER.

It is designed to break the coal to the size of walnuts or marbles, to be followed by the usual processes of classification and washing to remove the slate and sulphur before charging the coal into the coke oven.

It is applicable to all coals requiring cleansing by crushing and washing.

THE DISINTEGRATOR.

This is a strongly made machine to pulverize coal to a uniform fineness of cracked wheat or corn meal. Fig. 6 shows a general view of it.

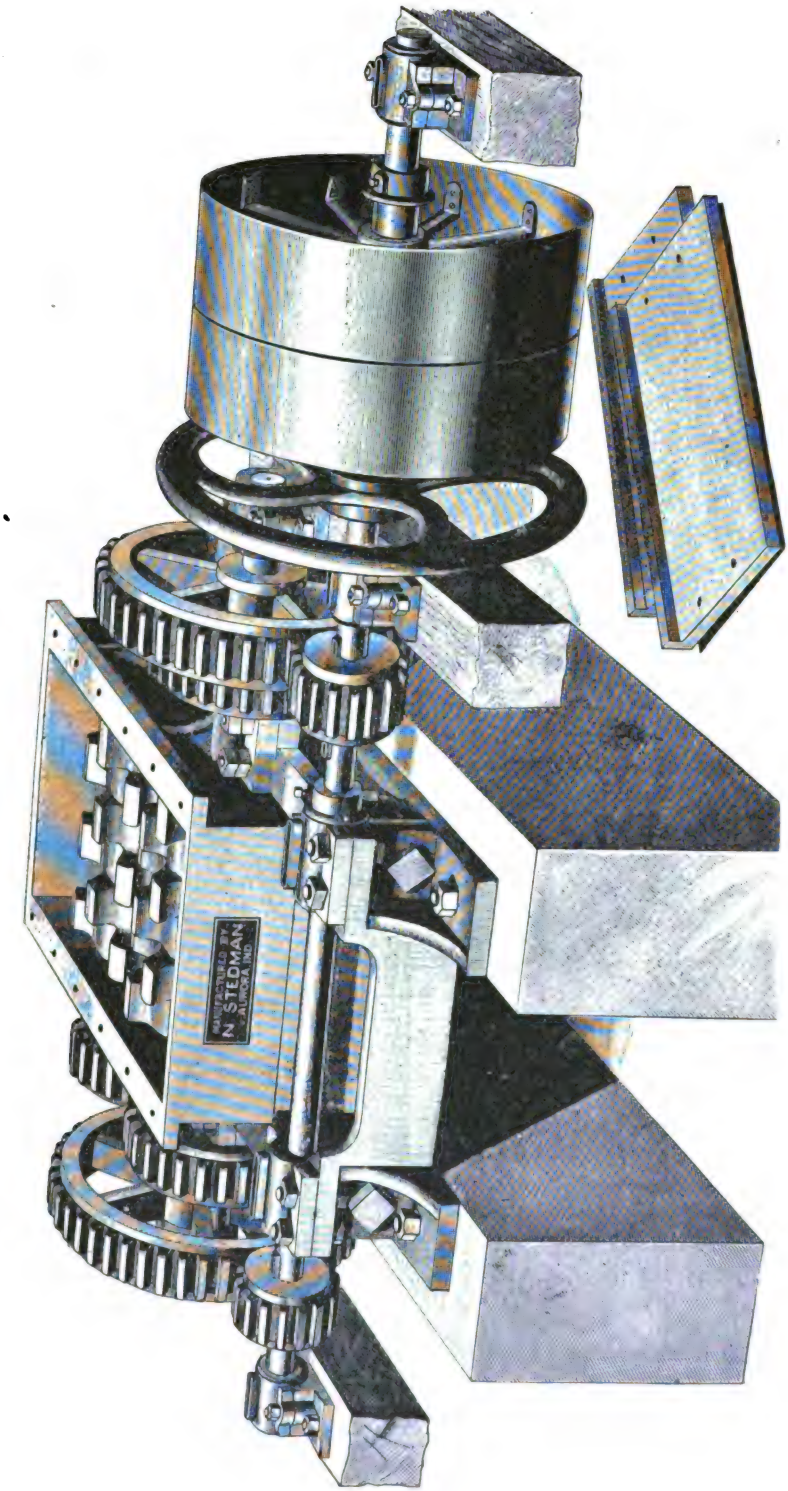


FIG. 6.—STEDMAN'S DISINTEGRATOR.

It is designed for use in treating the purer coals that do not require to be washed.

This treatment of coal for coking is helpful in utilizing the volatile matters, especially in coals inheriting small volumes of fusing matters, as it enables the heat of the oven to be diffused simultaneously through the charge of coal, quickly fixing and securing the utmost possible fusion of the coal in the process of coking.

The matter of determining the size to which the coal should be broken, by either of these machines, can be determined by the quality and chemical composition of the coal.

Coals with ample volatile matter can be broken into the larger sizes ; the coals low in volatile matters must be reduced in size according to their composition.

The same consideration will apply to the preparation of similar kinds of coals requiring the additional treatment of washing.

These matters are mainly local and practical. The manufacturer of coke will be called upon to exercise judgment in this preparatory treatment of coal from his experience in the ultimate evidence in the work of the coke oven.

The following statements exhibit the estimated cost and work of these machines :

CRUSHING PLANT, 200 TONS DAILY.

1	40″ Class A Coal Disintegrator complete. Capacity 175 to 200 tons daily of 10 hours. Power required, 1 horse power for every 4 or 5 tons of coal to be ground. Space occupied by disintegrator, 8x6 ft. Price complete, F. O. B. cars, Aurora	$550.00
2	9x14 Engines complete, connected at right angles with two (2) 54″ band wheels 12″ face on the main shaft to drive to the two pulleys on the Disintegrator. Engines speed at 175 revolutions per minute, developing 45 to 50 horse power. Engines complete with band wheels, automatic stop governor, throttle valve, spanner wrenches, cylinder cocks, lubricator, oil cups, anchor bolts and plates. Blue print drawings for foundation are furnished. Price complete, delivered on cars	550.00
1	4″ Tubular Boiler 54″ diam., 14 ft. long, will develop 60 horse power. Complete with all necessary trimmings and settings, consisting of fire front, grate bars, bearing bars, back plate, soot door and frame, check, blow-off and stop valves, whistle, steam gauge, gauge cocks, water gauge, chimney and breeching, guy rods, safety valve and weight. All pipes and connections between engines and boilers are extra. Price complete, F. O. B. cars, Aurora	640.00
1	Duplex Pump to supply boilers with water, and pipe and fittings for same	100.00

SUMMARY.

1	40″ Class A Disintegrator, complete as described	$550.00
2	9″x14″ Engines complete, coupled at right angles	550.00
1	Boiler 54″ diam., 14 ft. long and trimmings, 50 H. P.	640.00
1	Duplex Pump and fittings, as described	100.00
		$1,840.00

ELEVATOR, CAPACITY 200 TONS, TEN HOURS. SINGLE STRAND.

HEAD.

1	Head Shaft 2 7-16"x48" long	$15.20
2	Pillow Blocks 2 7-16" long	
2	Collars 2 7-16"	
1	24" No. 108 Sprocket Wheel	
1	Key	

ELEVATOR BOOT.

1	12x7" Cast Iron Boot complete with shafts, adjustable boxes, sprocket wheels and collars	$42.00
	Price per foot for No. 108 Chain and Elevator Buckets	8.00

CRUSHING PLANT, CAPACITY 250 TONS DAILY.

1 44" Class A Disintegrator complete $700.00
Capacity 200 to 250 tons daily. Power required, one horse power for every four or five tons of coal crushed daily. Space occupied by Disintegrator, 9'x6'.

2 11"x18" Engines connected at right angles with two 60" band wheels on the main shaft to drive to the two pulleys on the Disintegrator. Engines' speed, 150 revolutions per minute, developing from 75 to 80 horse power. Engines are complete with two 60"x12" pulleys on the main shaft, automatic stop governor, throttle valve, spanner wrenches, cylinder, lubricator, oil cups, cylinder cocks, anchor bolts and plates and blue print drawings for foundation. Price complete as described, F. O. B. cars, Aurora 738.00

1 4" Tubular Boiler 62" diam., 16' long, 90 horse power, complete with chimney and breeching, guy rods, fire front, grate bars, bearing bars, back stand, back plate, soot doors and frame, anchor bars, tie rods, safety valve and weight, check valve, stop valve and blow-off valve, whistle, water and steam gauge, feed pipe and connections. In fact, boiler with all settings and trimmings. Price delivered on cars, Aurora 895.00

1 Duplex Pump to supply boiler with water and all fittings and connections to connect to boiler 175.00

COST OF MACHINERY AS DESCRIBED.

1	44" Disintegrator as described	$700.00
2	11"x18" Double Engines, 75 to 80 H. P	738.00
1	62" diam., 16' long 4" tubular boiler, 90 H. P.	895.00
1	Duplex Pump as described	175.00
	Total cost	$2,508.00

ELEVATOR 250 TO 275 TONS' CAPACITY IN 10 HOURS' RUN. DOUBLE STRAND.

HEAD.

1	Head shaft 2 7-16" diam., 6 ft. long	$21.50
2	2 7-16" Pillow Blocks	
2	2 7-16" Set Collars	
2	24" No. 83 Sprocket Wheels	
2	Keys	

ELEVATOR BOOT.

1 14"x7" Cast Iron Boot complete with shaft, 2 sprocket wheels, adjustable bearings and collars $47.00
Price per foot for No. 83 double chain and buckets 3.65

CRUSHING PLANT, CAPACITY 350 TO 400 TONS DAILY.

1 50" Coal Disintegrator complete $900.00
Capacity 350 to 400 tons daily of crushed coal. Power required, 1 horse power for every four or five tons crushed coal daily of ten hours. Space occupied by Disintegrator, 10x8 ft. Weight complete, 17,000 pounds.

2 13"x20" Engines complete, connected at right angles with two band wheels 78" diam., 16" face on the main shaft to drive the two pulleys on the Disintegrator. Engines speed at 140 revolutions per minute, developing from 110 to 120 H. P.; engines complete with band wheels, automatic stop governor, throttle valve, spanner wrenches, cylinder cocks, lubricator, oil cups, anchor bolts and plates. Blue print drawings for foundation furnished. Price complete, F. O. B. cars, Aurora $1,000.00

2 4' Tubular Boilers, 130 H. P., 54" diam., 14 ft. long, complete with all necessary fittings and trimmings, consisting of fire front, grate bars, bearing bars, back plate, soot door and frame, check, blow-off and stop valve, whistle, steam gauge, gauge cocks, water gauge, chimney and breeching, guy rods, safety valve and weight. All pipe connections between engines and boilers are extra. Price complete, F. O. B. cars, Aurora $1,275.00

1 Duplex Pump to supply boilers with water and pipes and fittings for same ... 150.00

SUMMARY.

1	50" Disintegrator complete as described	$900.00
2	13"x20" Engines as described	1,000.00
2	Boilers 130 H. P., 54"x14'	1,275.00
1	Duplex Pump to supply boiler with water	150.00
	Total	$3,325.00

ELEVATOR 350 TO 400 TONS CAPACITY, 10 HOURS. DOUBLE STRAND.

HEAD.

1	Head Shaft 2 15-16" diam., 5' 6" long	$30.00
3	Pillow Blocks 2 15-16" diameter	
2	Set Collars 2 15-16" diameter	
2	25" diam., No. 108 Sprocket Wheels	
2	Keys for Wheels	

ELEVATOR BOOT.

1 18"x8" Cast Iron Boot complete with shaft, two No. 108 sprocket wheels, adjustable bearings and collars $60.00
Cost of Elevator chain and buckets per running foot 5.00

ESTIMATE.

1 60" Class A Coal Disintegrator, complete with fly wheels, pulleys, etc. Capacity, 500 tons in ten hours and upwards. Weight, 18,000 pounds $1,000.00

2	14"x20" Engines of the Houston, Stanwood & Gamble pattern, coupled at right angles with two band wheels 84" diam., 16" face to drive the belts running direct to Disintegrator, engines run at 130 revolutions per minute, developing about 125 to 135 H. P. Engines are complete with governor, two band wheels, throttle valve, spanner wrenches, automatic sight feed lubricator, oil cups and cylinder cocks. All pipe fittings and connections are extra. Price of engine as described	1,064.00
2	Tubular Boilers 60" diam., 16 ft.; rated at 160 H. P., complete with all necessary trimmings, consisting of fire front, grate bars, bearing bars, back plate, soot door and frame, check, blow-off and stop valve, whistle, steam gauge, gauge cocks, water gauge, chimney and breeching, guy rods, safety valve and weight. All pipes and connections between engines and boilers are extra. Price complete, F. O. B. cars, Aurora	1,650.00
1	Duplex Pump to supply boiler with water and pipe and fittings for same	175.00

SUMMARY.

1	60" Disintegrator complete as described	$1,000.00
2	14"x20" Engines as described	1,064.00
2	Boilers 160 H. P. as described	1,650.00
1	Pump to feed boiler	175.00
		$3,889.00

ELEVATOR 550 TONS CAPACITY.

HEAD.

1	Head Shaft 3 7-16" diam., 6 ft. long	
3	Pillow Blocks 3 7-16" diameter	
2	Collars 3 7-16" diameter	$41.00
2	30" No. 108 Sprocket Wheels	
2	Keys	

ELEVATOR BOOT.

1	Cast Iron Boot for 24"x10" buckets complete with shaft, two sprocket wheels, adjustable bearings and collars	75.00
	Price per foot for No. 108 double elevator chain and buckets	6.50

These or similar coal breaking machines are now coming into more general use in the preparation of coal for use in mechanical stokers, as it must be reduced to a certain maximum size to be available in these mechanical appliances for firing boilers.

When they are used in disintegrating coals which require the further process of washing, their work ends when the coals are reduced to such sizes as are required to meet the wants of the washing apparatus.

It is evident that, in this preparatory work, the chief requirement is to remove all the larger pieces of slates, pyrites or other impurities possible, and thus reduce the work of the washer.

During the past half century, especially in continental Europe, very much attention has been given to mechanical appliances for washing coal.

The most primitive of these consists in a long wooden trough, divided by low cross section dams at intervals along its course. The inclination of

this sluice is usually made to give sufficient force to the water passing through it to separate the coal from the slate; the latter remaining in the upper recesses of the dams, whilst the coal is carried over, screened and delivered into a car or other receptacle at the lower end of the sluice.

The slates are removed at stated intervals by an attendant with a rake.

The prepared coal and the water for its cleansing are received together at the upper end of the trough. The following plan and section, Fig. 7, will make this old time washer and its operations easily understood.

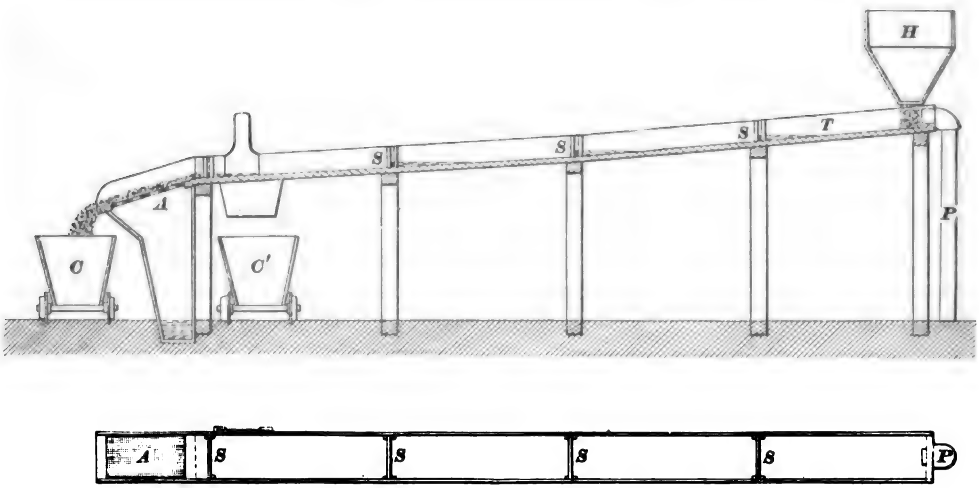


FIG. 7.—PLAN AND SECTION OF TROUGH WASHER.

T, Trough. *S*, Dams. *A*, Screen. *H*, Hopper for delivery of coal. *P*, Stand Pipe for applying water. *C*, *C'*, Cars for washed coal and slates. This wooden trough is usually 80 to 100 feet long, 2 to 4 feet wide and 12 to 15 inches deep.

An improvement has been made on this "trough washer," which adds very much to its efficiency, economizing labor and water in the process of washing.

The following plan, section and description, Fig. 8, are taken from *The Colliery Guardian*, London, of a recent date, November 16, 1894.

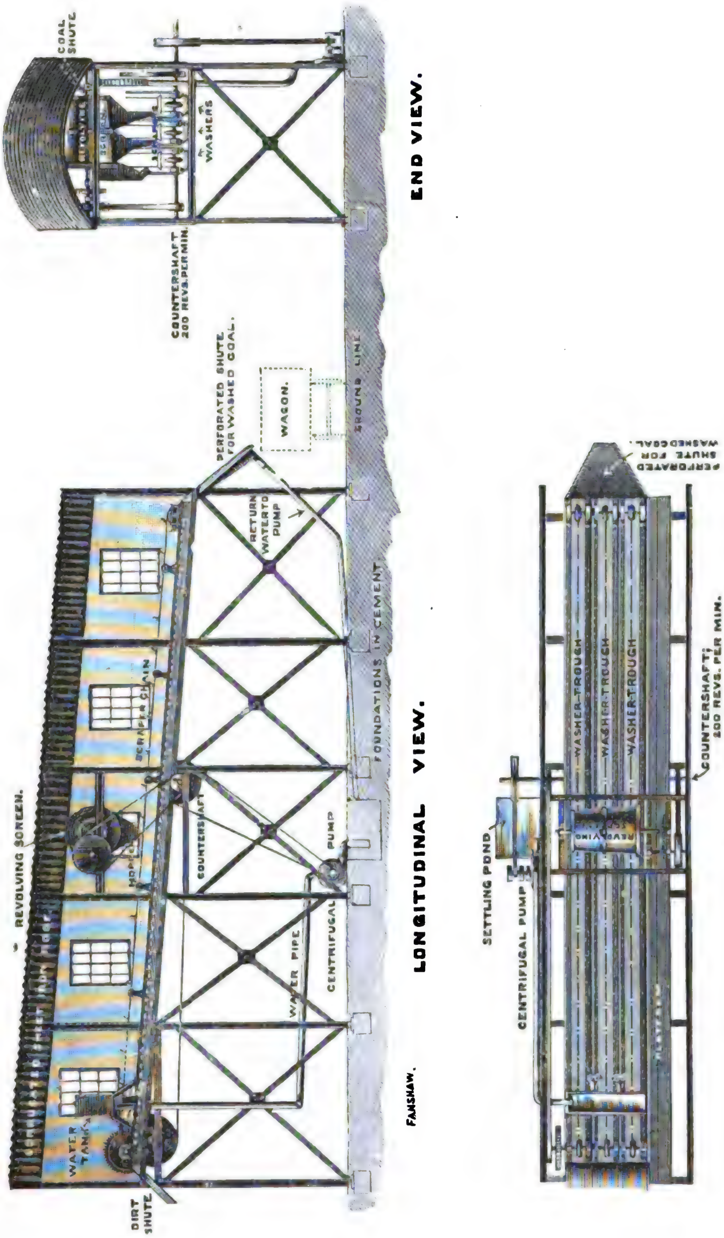


FIG. 8.

This machine has been designed on the lines of the old trough washer, which has long been a favorite with many colliery engineers on account of its simplicity and its efficiency when in the hands of an intelligent, trust-

worthy attendant. But in addition to the difficulty of always obtaining the necessary skill and attention, there was also in the old troughs the necessity of changing the flow of coal and water into a second trough while the dirt was being washed off and removed from the first, when the stops had become charged with it; for if this was not done at the proper time some of the dirt became mixed with the coal and the result was not satisfactory. The Elliott washer, as shown in Fig. 8, is claimed to be automatic in its action, and retains all the advantages of economy and efficiency of the old trough, without any of its disadvantages, and is independent of the skill or attention of the attendant, the operation of washing proceeding without interruption as long as required, the coal being delivered at one end of the trough with the water, and the dirt at the opposite end.

The washer is constructed with a wrought iron or steel trough about 18 in. wide, having sloping sides, being widest apart at the top and narrowest at the bottom. At each end of this trough a sprocket wheel is fixed, on which a chain rides, and attached to the chain at suitable distances are scrapers at right angles to it, and which correspond to the inside shape of the trough. The scrapers form movable stops or dams which are slowly moved by the chain along the trough in the opposite direction to the way the water runs. The trough is fixed at a suitable inclination, and the coal is admitted at the centre of its length and the water at its highest end or thereabouts, and as it runs to the lowest end it carries with it the coal, which is lighter than the dirt, and the dirt settles in the scrapers and is conveyed by them against the stream of water and delivered at the opposite end to that at which the coal escapes. The speed of the scrapers and quantity of water is regulated to suit the material washed. The water is circulated and used continuously, so that the waste is that only which is carried away by the dirt and coal after drainage. A centrifugal or other pump is used for elevating the water to the washer. The arrangement for draining the water from the coal is such that there is no waste of coal, or pollution of streams, etc. A pipe 1 in. diameter will keep good the supply of water for each trough, or 100 tons of coal washed per day. This washer is being introduced by the Hardy Patent Pick Company, Limited, of Sheffield, Eng.

It is evident that this class of coal washers require large quantities of water, and their work is somewhat expensive and imperfect.

To economize water and separate the impurities from the coal in a more complete and economical manner, an improved class of washing machines have been introduced. These have now displaced the older methods.

A current of water for separating prepared coal from its slates, is produced by a plunger at one side of the machine, which pulses the water upward through the coal in an adjoining chamber. By this operation the lighter pieces of coal are carried up and over the edge of a place for its discharge, whilst the heavier pieces of slate and pyrites sink to the bottom and are removed at stated intervals.

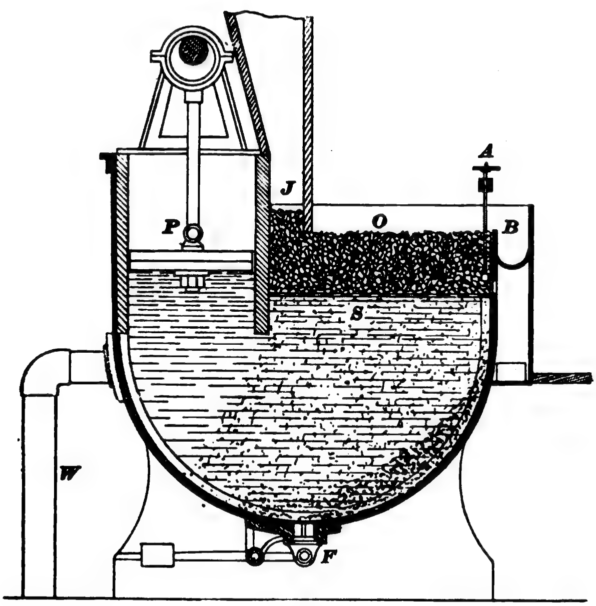
The force of the upward pulsing current is regulated so as to meet the requirements of, the several varieties of coals, in the process of removing their impurities. If this current is too strong it will disarrange the classification of the coal; if too weak, it will fail to separate the larger pieces of coal.

It is also important, that the force of the upward pulsing current be uniform in its action through the mass of coal in the washer chamber of the apparatus, otherwise imperfect work will ensue.

Mr. H. Rittinger, who has given the mechanical separation of materials considerable study, has from practical tests deduced the following formula.

The velocity of the current in feet per second is equal to 1.28 $\sqrt{D(d-1)}$, in which d is the density of the material and D the diameter of the meshes in the screen, or practically the diameter of the pieces to be operated on.

The following illustration of the Hartz jig, Fig. 9, will convey the general principles of the operations of this class of coal washing machines.



P, Plunger.

J, Feeder, prepared coal.

W, Water supply.

S, Water chamber.

O, Coal chamber.

A, Slate delivery.

B, Clean coal discharge.

F, Slates removed here.

Capacity, about 150 tons per day.

Cost, about 5 cents per ton

FIG. 9.—HARTZ JIG.

The Bérard's coal washing machine was introduced to public notice in London in 1851, and in Paris in 1855.

It was used by the Kemble Coal and Iron Company, in the Broad-Top region, Pennsylvania, a few years, beginning in 1873.

The sectional drawing, Fig. 10, will make its operations intelligible.

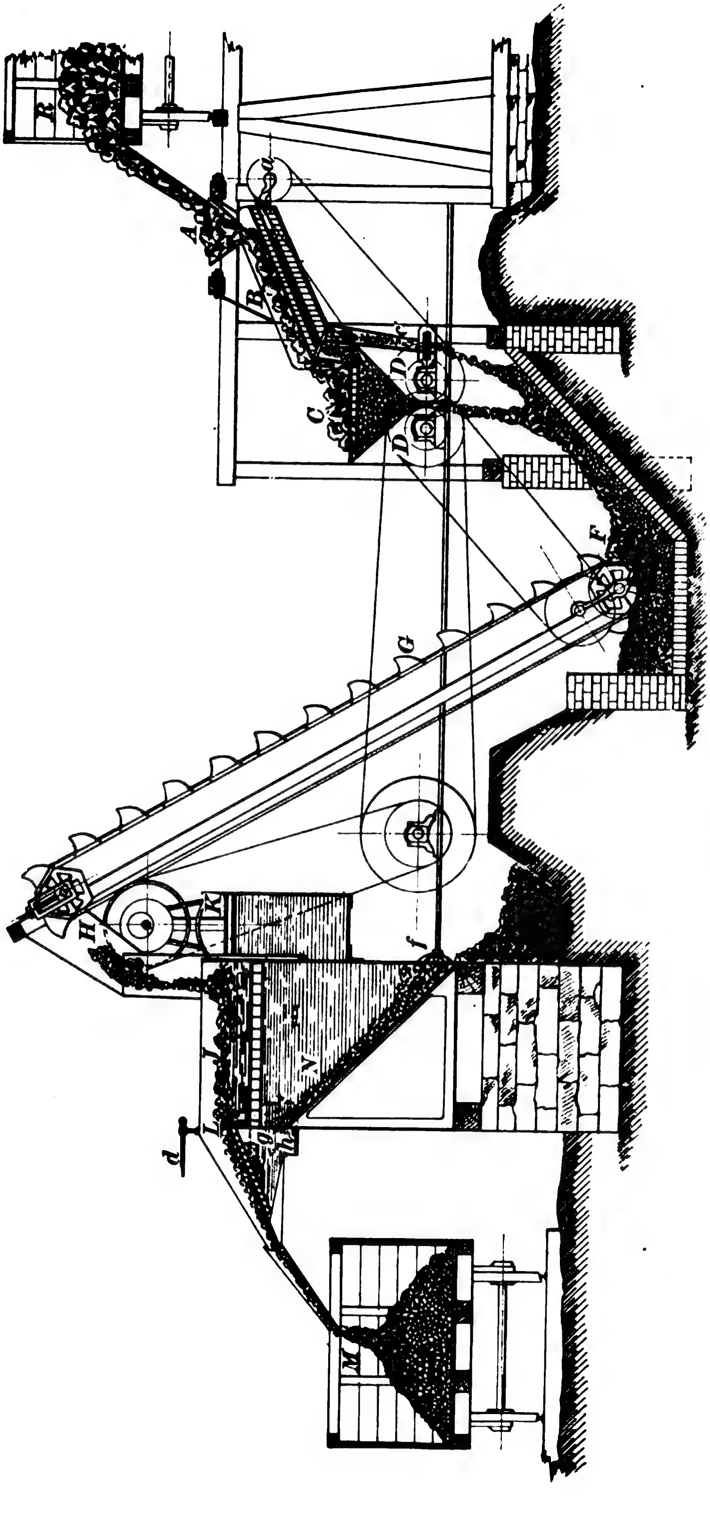


FIG. 10.—BÉRARD'S COAL WASHING MACHINE.

The coal to be cleansed is dumped into the hopper *A*, from the railroad car *R*, by a side door over an iron chute; from thence it is diffused on the separator *B*, which is kept in agitation by the cam *a*. The large lumps, which will not pass through the 3 inch square openings in *B*, roll down to the screen platform *C*, where they are broken by a workman with a maul, and falling through the grating, pass to the rolls *DD*.

The smaller lumps pass through the 3 inch meshes in the agitator screen *B*, when they are further divided by a screen underneath *B*. The portions of the coal which will not pass through the ½ inch holes in the latter screen, pass directly to the rolls *DD*, whilst the very fine portion is carried under the rolls, down the chute *C″*, into the receiver *F*. The rollers *DD* have teeth or spurs set all over their circumference, each being about ½ inch square by ½ inch high. Their arrangement is such that the spurs of one roll mesh into those of the other. One of the crushing rolls has its pillar blocks set in sides, with a rubber ball spring, so as to admit a small horizontal movement to prevent the breaking of the teeth of the rolls by the passage of hard slates or pyrites.

After passing the rolls, the crushed coal falls into the receiver *F*, whence it is elevated by the chain of buckets *G* and delivered into the chutes *H*, through which it is carried into the separating pans *J*, made of cast iron, with a copper plate on top of the grating, forming the bottom of the iron pan; the copper plate is perforated with ⅛ inch holes, set close together.

The pans are supplied with water conveyed into them by troughs, through which also the coal is carried. The action of the piston *K*, which moves with quick, short strokes (120 per minute), forces the water through the coal and slate in rapid pulsations, lifting the pure coal upward and onward with the movements of the water until both are carried over the side of the pan at *L*, and thence over a grated chute into the car *M*, on the track in front of the washer.

The impurities, being heavier than coal, sink to the bottom of the pan and are carried to its front interior angle, whence they are discharged by a valve *d*, into the receiver *N*, from which they can be removed by a sliding bottom *f*. The movement of the mass of coal in the pan is about 20 inches per minute, giving a continuous overflow of washed coal into the receiving cars below. This flow can be regulated by raising or lowering the front side of the wash pan at *L*.

The main portion of the water in the washed coal is drained from it by a zone of fine copper wire screen on a chute, immediately under the discharge from the wash pan at *L*. This water, charged with the very fine coal and dust, passes through *g*, and is conveyed by a trough *h*, into a large tank alongside the washer, where the fine coal is permitted to settle, and from which it is shovelled into the receiving cars, along with the coarser coal, and all charged into the coke ovens.

This washer with three pans is capable of cleansing 12½ net tons of coal per hour, or 125 tons per day of 10 hours.

The cost of machinery was $9,000, erecting $3,000; making a total cost complete of $12,000.

Mr. William Lauder, superintendent, reported the cost of washing at 21½ cents per ton. This covers interest on investment, and all other expenses.

The coal to be treated was "run of mine," from the Kelly seam, and inherited the following composition:

Moisture	0.043
Volatile Matter	19.637
Fixed Carbon	71.564
Ash	7.056
Sulphur	1.700

Coke made from the washed coal gave ash 9.66 per cent., and sulphur only 1.06 per cent.

After a few years' washing at this place, the process was discontinued. This was brought about by improvements in mining the coal, especially in rejecting a thin section of the coal at the floor of the bed. With this separated, it was found that good coke could be made from the coal, with careful mining, without the further expense of processes of crushing and washing.

The importance of constant care in mining coal for the manufacture of coke, cannot be too earnestly urged on the management of the mines. This is especially true in the mining of coal beds inheriting slate partings, as the sulphur will generally be found in these. In some instances coal beds have sections of their coal at the roof or floor, largely impregnated with sulphur; by carefully rejecting and removing thin portions of the coal, very much will be contributed to its ultimate cleansing.

THE STUTZ IMPROVED COAL WASHER.

This machine, illustrated below, Figs. 11 and 12, has been tested in practice during many years. It is simple in its construction, yet efficient in its operations, requiring a small force in working it.

It was designed by S. Stutz, Mining and Mechanical Engineer of Pittsburgh, Pennsylvania, who has followed up its workings, adding from time to time such improvements as appeared necessary to make its processes more complete.

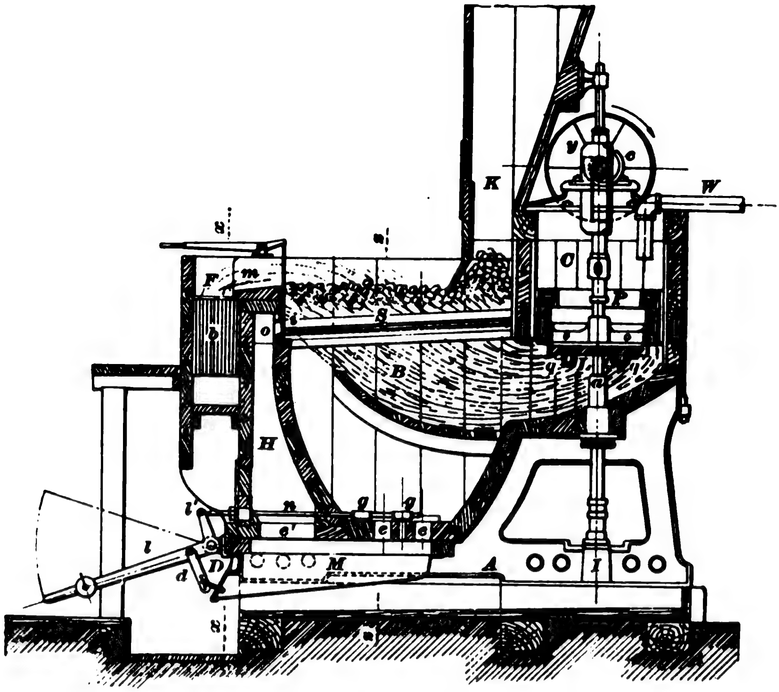


Fig. 11.—THE STUTZ IMPROVED COAL WASHER.
Longitudinal Vertical Section.

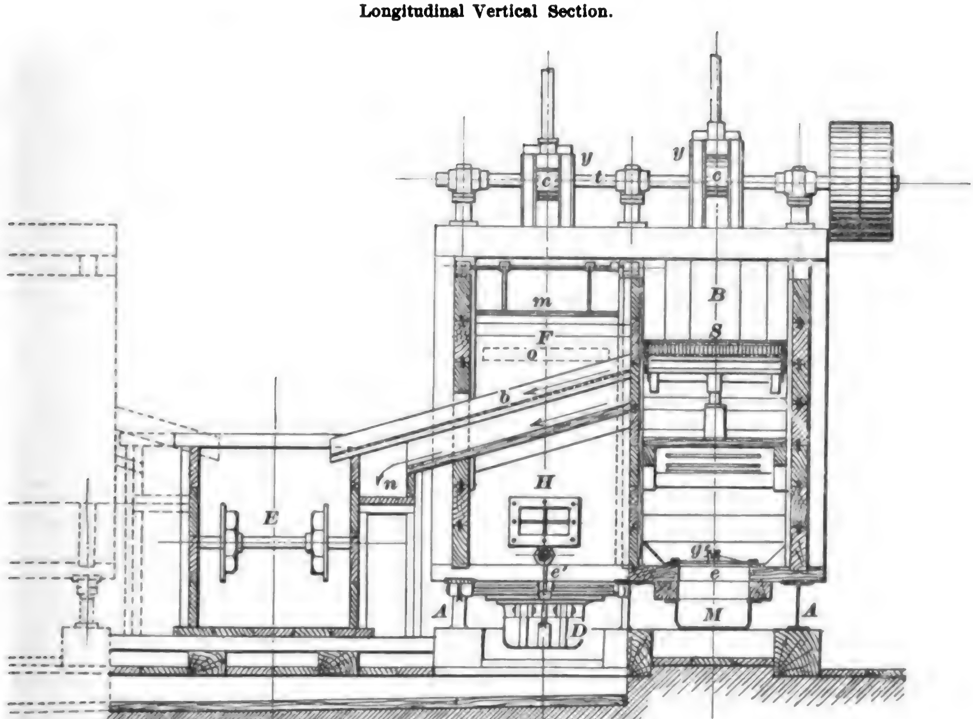


Fig. 12.—THE STUTZ IMPROVED COAL WASHER.
Transverse Vertical Section

Fig. 11 is a longitudinal vertical section, and Fig. 12 represents a vertical cross-section at the lines x x and z z of Fig. 11.

In these figures, *A A* are cast iron brackets, supporting a rectangular box, divided into chambers *B*, *C* and *H*, constituting two complete machines.

Arranged within the chamber *B* is a screen or sieve *S*, while the chamber *C* contains the piston or plunger *P*, with its mechanism to reciprocate vertically.

H is the slate chamber which communicates with the separating or washing chamber *B* through an opening *o*, governed by a suitable valve, *i*.

F shows a trough or chute, provided with a screen *b*, and communicating with the separating chamber *B*, to receive the washed coal as it passes over the bridge *m*. Beneath the slate chamber *H* and the separating chamber *B*, an auxiliary receiver *M*, is arranged, which communicates with both chambers by means of the openings *e′* and *e e*, for the purpose of providing means to collect the sediment which passes through the meshes of the sieve *S* during the operation of the machine, and to effect its escape without wasting the water in the washing chamber *B*, thus making the operation of the washer continuous.

Before letting the fine sediment to the outside, the openings *e e* are closed by the gates *g g*, and the communication with the washing chamber *B* is shut off. No water is wasted. The receiver also collects the coarse impurities from the slate chamber *H;* both kinds, coarse and fine, may be let to the outside of the machine by the levers *l l′*.

The piston or plunger *P*, is provided with large openings *O O*, in its bottom ; they are governed by floating valves *L* underneath, kept in proper position by guides *q q*. With the improved plunger the necessary volume of water is let into the machine from above by means of the pipe *W*, thus filling up more easily the entire space when the piston is moving upward. Movement is imparted to the latter from the shaft *t* by means of the cam *c*, yoke *y* and rod *a*.

Coal to be washed is supplied to the screen *S* through a hopper *K*. The separation of the coal from its impurities is accomplished in the usual way. The pulsations of the water by the movements of the plunger lift the lighter coal upwards, whilst the slates, pyrites, etc., sink to the bottom. The stroke of the plunger can be varied to meet the wants of the different sizes of coal.

THE STUTZ IMPROVED COAL-JIGGING AND WASHING MACHINE.

Fig. 13 represents an "Improved Coal-Jigging Machine," with a vertically reciprocating piston or plunger directly underneath the stationary sieve or screen.

In the upper right corner is a longitudinal vertical section through the center of the jigger. Adjoining it is a section taken at line *x x* of the top view shown below, and a front elevation of two machines combined together.

In the drawings *A A* represent cast-iron brackets supporting the separating box *B*. Arranged within the latter is the screen or sieve *S*, with the piston or plunger *P* below, and the mechanism whereby the latter is caused to reciprocate vertically above. *H* is the slate chamber, which communicates with the washing chamber *B* through the opening *o*, governed by the valve *i*. *F* represents a trough or channel, also communicating with the washing-chamber *B*, and designed to receive the washed coal as it comes over the delivery bridge *m*. *M* is an auxiliary receiver, arranged beneath the chamber *B*, and communicating with the latter by means of openings *e e*, governed by gates *g g*. The recevier *M* also communicates with the slate chamber *H*, through the opening *e'*, for the passage of the coarse impurities. *D* is the outlet gate or door of the auxiliary receiver and is connected to bell-crank levers *l l'* by links *d*.

Movement is imparted to piston *P* by means of eccentrics *c c*, keyed upon the driving shaft *t* and yokes *y y*, connected to rods *a a*.

Coal is fed upon the screen *S* from the hopper *k*, while the supply pipe *W* furnishes the necessary volume of water for the operation.

The purpose of the auxiliary receiver *M* is to provide means for collecting the fine sulphur and slate pieces which pass through the meshes of the sieve *S* during the working of the machine, and to effect the escape of said fine sediment without wasting the water inside the washing chamber *B*, thus making the operation of the jigger "absolutely" continuous.

By means of the improved and special shaped piston *P*, acting at each up-stroke like a wedge behind the material upon the screen, the different layers of the separated substances, coal and impurities, are readily and uniformly advanced towards the delivery openings, while below the screen the filling up or choking by the fine sediment passing through its meshes is also prevented.

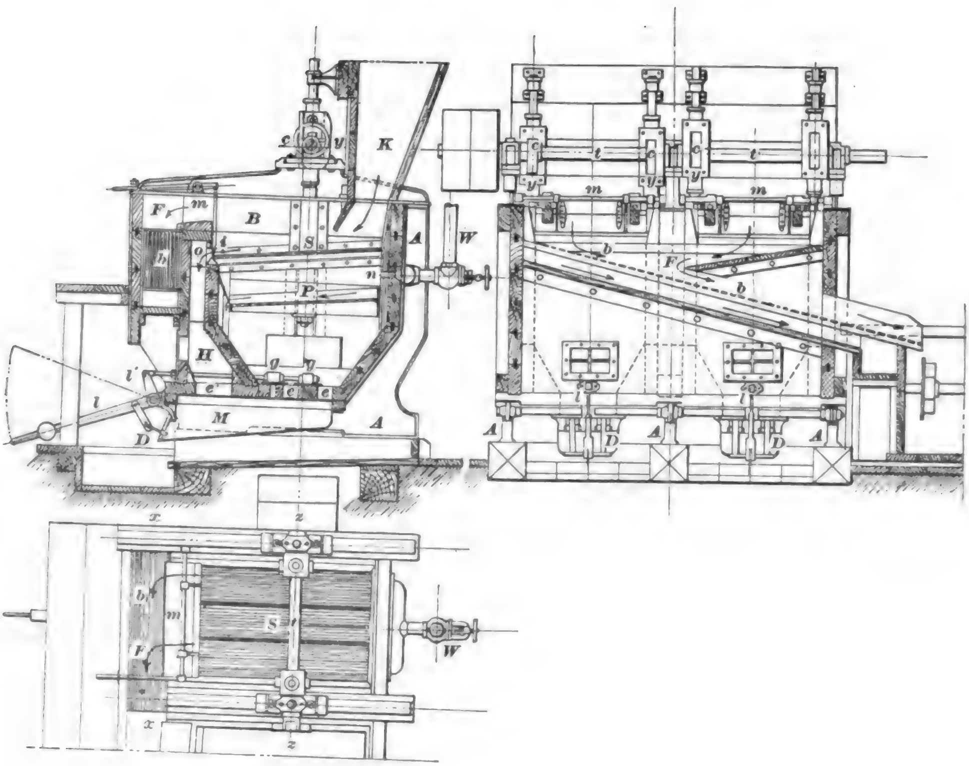


FIG. 13.—STUTZ IMPROVED COAL JIGGING AND WASHING MACHINE.

The cost of these coal washing machines, for cleansing 300, 400 and 600 tons per day, will depend mainly on location, quality of coal to be treated and the character of its impurities.

Mr. Stutz has furnished estimates for the treatment of the above outputs per day of ten hours at $10,000, $12,000 and $15,000, respectively. This estimate includes the necessary power, water and building. It does not, however, embrace the machine for disintegrating the coal in the preparatory process. The cost of this will be found under the head of coal crushers or disintegrators.

The cost of washing is given at 1½ cents per ton for the work of washing alone. The interest on investment of plant, the wear and repair of machinery must be added to show the total cost of cleansing the coal in this machine.

There are also in operation a large number of other machines for washing coal. Many of these possess great merit, but it is impossible in the bounds of this volume to notice all of them.

The typical machines, it is believed, have been described and illustrated.

The foundation principle in all of these useful appliances for cleansing coal is, that the difference of specific gravities of the coal and its impurities is utilized in separating them by pulsing movements in a water bath.

It is also evident that, as a preparatory operation, for coal requiring washing, it should receive careful treatment in its disintegration and classification before charging into the washing or separating chamber. Recently much attention has been given to perfecting these two preparatory processes.

WALTER M. STEIN'S WASHERS.

Figs. 14, 15 and 16 show Mr. Stein's standard jigs, and Fig. 17 shows the general arrangement of a coal washing plant designed by Mr. W. M. Stein, of Philadelphia, for the New Glasgow Iron, Coal and Railroad Company, of Nova Scotia.

The coal from the various mines arrives on the railroad tracks a_1 a_2 and is dumped into the pits underneath (a different kind in each pit). From these pits the coal is taken by means of bucket elevators c_1 or c_2, to the shaking screen *d*. This shaking screen has double eccentric motion, imitating hand screening as much as possible. The mesh of the screen plate is three-eighths inch.

The material too large to pass through the perforations drops into the crusher rolls e_1 and e_2, and is again taken, after the crushing, to the shaking screen *d* by means of the bucket elevator *f*.

The coal passing through the shaking screen *d* is taken by means of the bucket elevator *g* to the separating screen drum *h*, which separates it into three sizes—nothing to one-eighth inch, one-eighth to one-quarter inch, one-quarter to three-eighths inch.

The different sizes are carried by means of chutes to the various jigs J_1 to J_8. These are all two-compartment feldspar jigs, arranged with variable stroke. Each screen compartment is twenty-eight inches wide and forty-nine inches long, so that the coal must travel a distance of over eight feet while being washed.

The washed coal flows in gutters to the large elevator boot k_2, and is elevated from there to the top of the storage tower by means of the perforated bucket elevator l_2, which discharges on the distributing conveyor *m*, which carries it into the various compartments *n* of the large storage tower.

The two jigs shown in dotted lines, the elevator boot k_1 and the elevator l_1, are arranged to be put in if the plant requires enlargement.

The slate from jigs J_1 to J_8 is discharged into elevator boot q_1, and is taken from there by means of a perforated bucket elevator r_1, and dumped into railroad cars ready to be taken to a convenient dumping place.

The centrifugal pump *t* distributes the water, which, after being used always returns to the pump and is used over again. There is no loss in this respect except that absorbed by the coal, and enough fresh water must be added to make up for this.

u is the steam engine of 100 horse-power to drive the entire plant.

The elevators are all of special construction and have very large buckets automatic feed, etc., and are run at a slow speed.

As will be readily seen, the entire plant works automatically, requiring only three men to operate it.

The coal washed contains from 17 to 35 per cent. of ash, besides about 2½ to 3 per cent. of sulphur; the washed coal contains in the average 10 per cent. of ash or 1 per cent. more than the fixed ash, 9 per cent. of the coal. This is a remarkably good showing, and is seldom equaled at any washing plant in existence. The fixed ash cannot be reduced by any method. Coming within 2 per cent. of the fixed ash is ordinarily considered excellent work.

The sulphur is reduced by washing, from 2½ to 3 per cent. down to 1.35 per cent., that still left being the organic sulphur and that in combination with alumina or lime.

Jigs J_1 to J_5 were in the original plant; J_6 to J_8 were added when the additional retort coke ovens were built. The total capacity of the plant is now 300 tons of coal in ten hours.

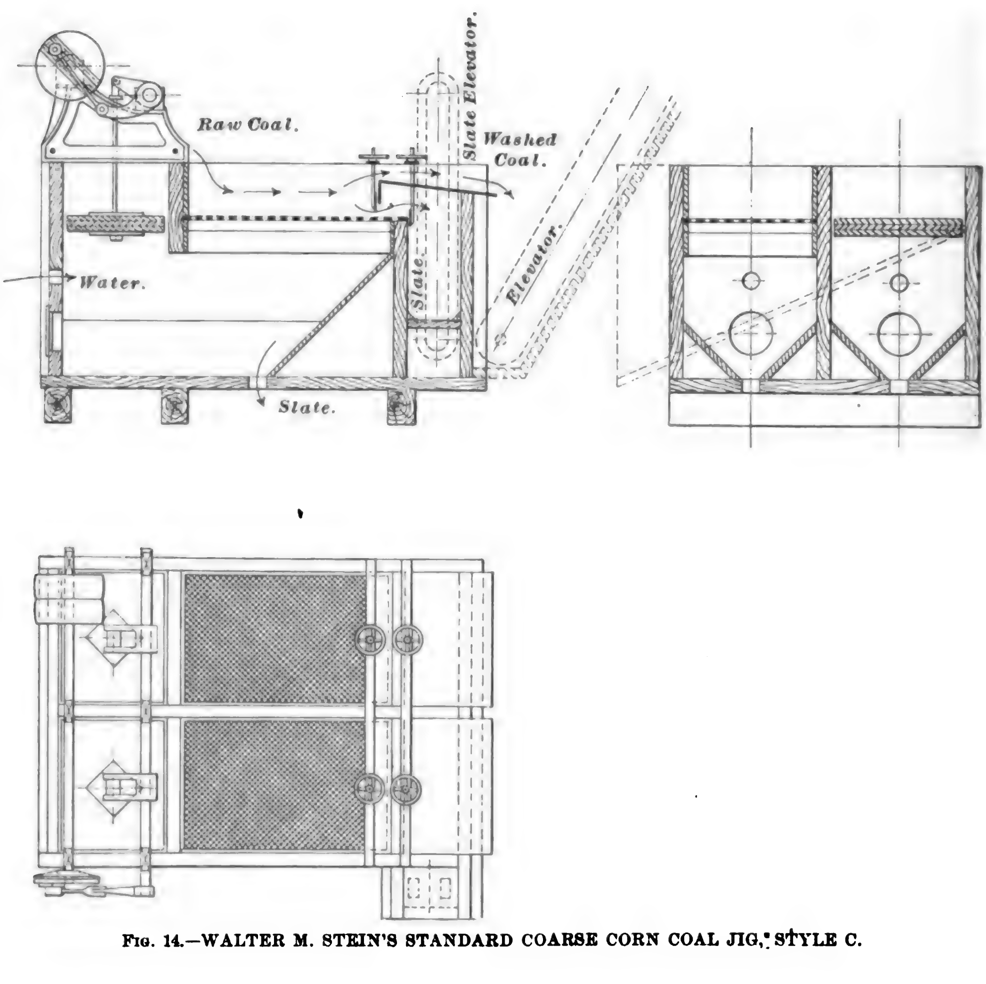


FIG. 14.—WALTER M. STEIN'S STANDARD COARSE CORN COAL JIG, STYLE C.

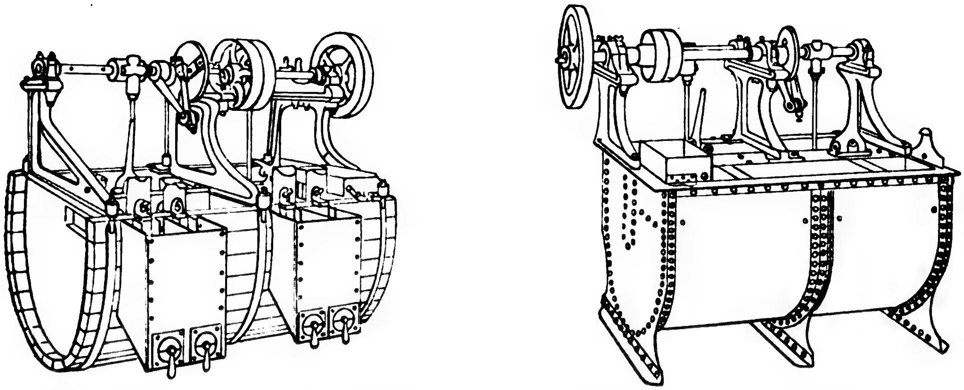


Fig. 15.—STEIN'S JIG FOR COARSE SIZES, STYLE G. STEIN'S JIG FOR FINE SIZES, STYLE H. WOOD OR IRON TANKS.

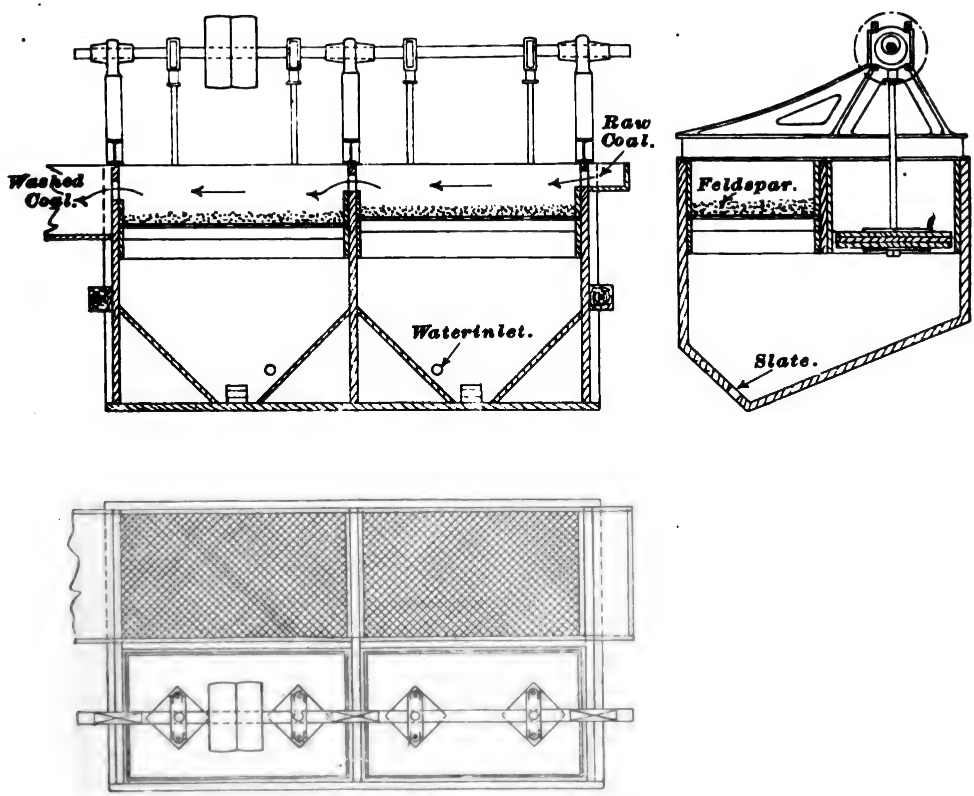


Fig. 16.—STEIN'S FINE CORN COAL JIG, STYLE A. TWO COMPARTMENTS, AUTOMATIC SLATE VALVE.

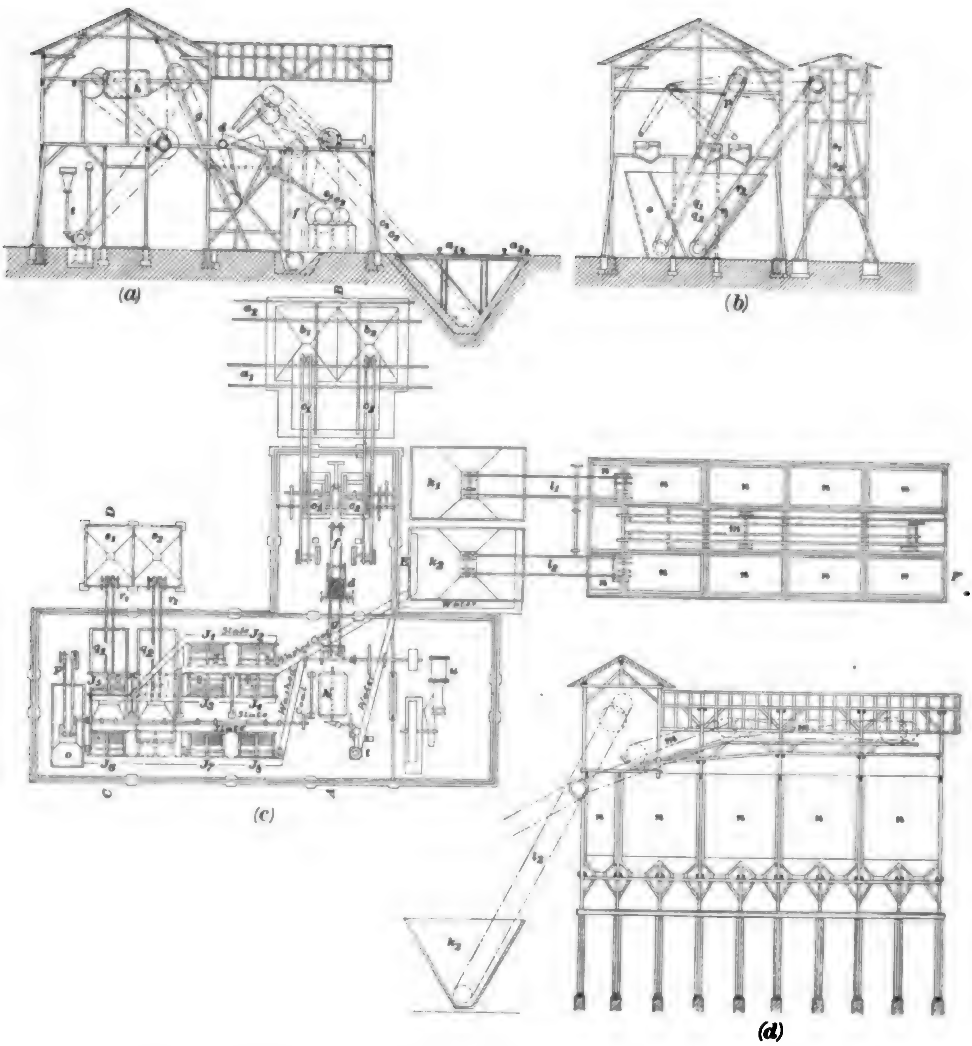


FIG. 17.—STEIN WASHER. BUILT FOR NEW GLASGOW IRON, COAL AND RAILROAD CO. OF NOVA SCOTIA.

THE COAL WASHING PLANT AT BROOKWOOD, ALA.

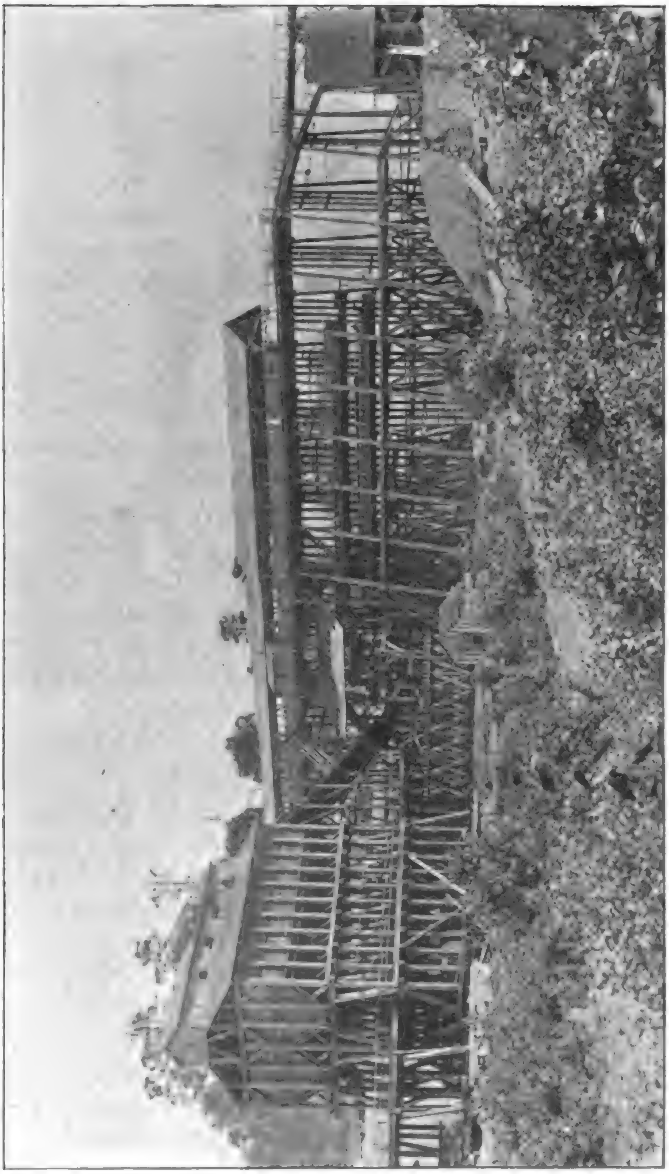
The plant was designed by Walter M. Stein, of Philadelphia, for the Standard Coal Company. The following description is by Rudolph Boericke, superintendent, and was written in response to a letter of inquiry addressed to Fred. M. Jackson, secretary and treasurer of the company:

The coals is drawn up the mine slope by wire rope haulage, to the top of a wooden trestle some 50 ft. high, where it is dumped into a hopper. It passes first over a double table shaking screen which divides it into three sizes. The largest size, comprising nut and lump, passes over two picking bands, 73 and 68 ft. long, respectively, where it is hand picked by boys, and then over another screen which takes out the nut. The remaining lump is delivered to the lump loader. This latter consists of a chain of buckets or pans moving along on iron ways, and in operation it is exactly the reverse of an elevator—instead of raising the coal it lowers it into the car. The lower end swings on chains and can be adjusted to any height of car, or be raised clear of the train while the cars are being shifted. Now, to return to the coal which passes through the first or shaking screen. That part of it which is too small for nut, yet too large for washing purposes, falls directly to the crusher where it is crushed and returned to the shaking screen. The crushed coal and all the fine coal from the mine is sized in a large double revolving drum into three sizes, each size being washed through gutters to jigs adapted and adjusted to that particular size. There are 11 double compartment plunger jigs in all, each capable of handling from five to seven tons per hour. In these jigs the raw coal enters at one end, moves across both compartments, and out at the other end as the washed product. In moving across, the slate, pyrites, barytes and all heavier particles find their way down through the bed to the bottom of the jig and flow out through the slate valve in a constant stream.

The washed coal and the washed slate are each led by means of gutters to their respective tanks or boots, where perforated bucket elevators, moving slowly to drain off the water, raise and dump them. The slate elevator discharges into small cars which the picking boys push to the slate dump, and the washed coal is allowed to fall on the conveyor, which in turn carries it to the storage tower. The amount of water used in this plant is very small, as the same water is used over and over. By allowing it to flow through a settling tank, we not only obtain tolerably clear water, but save all the sludge or finer particles of coal, which are held in suspension and which would otherwise be lost. The capacity of the washer is 500 tons per day of 10 hours, though owing to the limited output of the mines at present it has not been handling much over 300 tons.

The following analyses show the efficiency of the washer very plainly. The coke is hard and exceptionally low in ash.

To obtain the average for a day's run in this table, samples of run of mine and of washed coal were taken every half hour:



COAL WASHER AT BROOKWOOD, ALA.—STORAGE TRESTLES.

Date.	Average percentage of ash in the run of mine.	Average percentage of ash in the washed coal.	Per cent. reduction in ash.	Average percentage ash in the coke.
December 21	15.32	8.15	46.9	10.10
" 23	14.10	7.50	46.9	9.50
" 31	15.07	6.50	56.8	.....
January 5	20.83	8.10	61.3	10.50
" 6	17.18	7.60	55.5	10.50
" 7	16.38	6.50	60.2	9.27
" 26	20.90	5.50	73.5	.....
" 27	17.37	5.40	69.0	.....
" 28	18.63	7.15	61.7	.....
February 13	21.12	4.81	77.5	6.10
" 14	.....	.....	.....	7.40
" 17	.....	.....	.....	7.80

The run of mine which is washed is a mixture of the No. 4 and No. 6 seams. That from No. 4 is finely interstratified with slate and contains an abundance of sulphur. There is a lack in sulphur determinations, but a casual examination of the washed slate and of the washed coal shows that it is removed almost entirely.

The washer is the first of its kind in the United States, though not in America, as there is a 300-ton plant in successful operation at Ferrona, Pictou County, Nova Scotia. The New Glasgow Iron, Coal and Railway Company operate it in connection with their blast furnace.

Mr. Stein writes that an addition will be made to the plant in the shape of a large elevator with automatic dumper for feeding coal from a storage bin. This will hold 250 tons of coal, and will enable the company to operate the washer to its fullest capacity during the day. Another perforated bucket elevator will also be added for removing the dust from the settling tank.

The sulphur has been reduced to 0.52, 0.54 and 0.53 per cent., from 1.65 per cent. of sulphur in the coal of one of the seams used in making coke, and 1.15 per cent. of sulphur in the coal of the other seam. This shows good work, with a very small loss of fine coal.

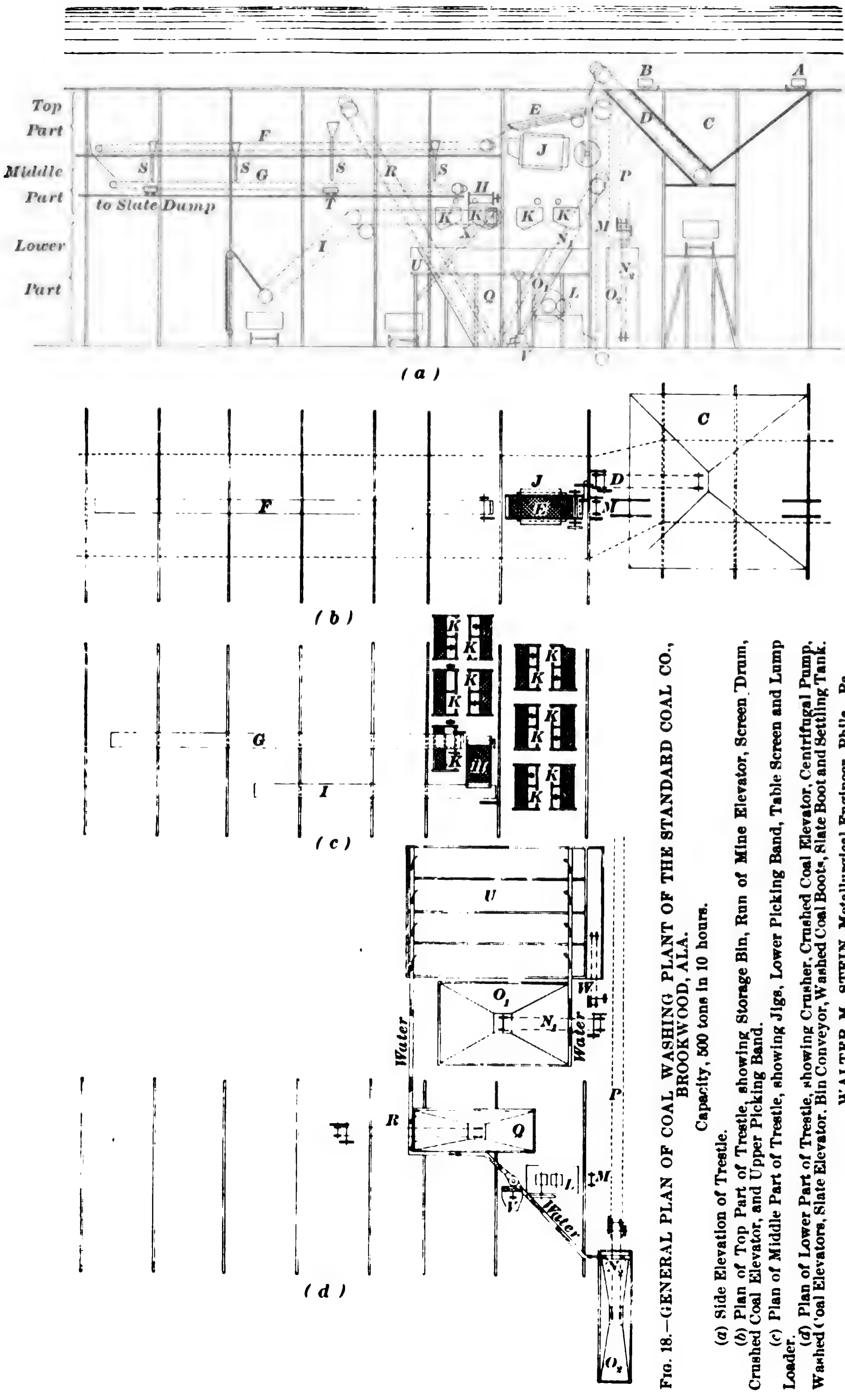


FIG. 18.—GENERAL PLAN OF COAL WASHING PLANT OF THE STANDARD COAL CO., BROOKWOOD, ALA.

Capacity, 500 tons in 10 hours.

(*a*) Side Elevation of Trestle.

(*b*) Plan of Top Part of Trestle, showing Storage Bin, Run of Mine Elevator, Screen Drum, Crushed Coal Elevator, and Upper Picking Band.

(*c*) Plan of Middle Part of Trestle, showing Jigs, Lower Picking Band, Table Screen and Lump Loader.

(*d*) Plan of Lower Part of Trestle, showing Crusher, Crushed Coal Elevator, Centrifugal Pump, Washed Coal Elevators, Slate Elevator, Bin Conveyor, Washed Coal Boots, Slate Boot and Settling Tank.

WALTER M. STEIN, Metallurgical Engineer, Phila., Pa.

References.

A	Tipple; Coal arriving from No. 3 and 4 Mine.
B	Tipple; " " " 6 "
C	Coal Storage Bin.
D	Run of Mine Elevator.
E	Double Shaking Screen.
F	Upper Picking Band.
G	Lower " "
H	Single Shaking Screen, 3″ Mesh to separate Lump and Nut Coal.
I	Lump Loader.
J	Revolving Screen Drum.
K	Jigs.
L	Crusher.
M	Crushed Coal Elevator.
$N_1 N_2$	Washed Coal Elevator.
$O_1 O_2$	" " Boots.
P	Bin Conveyor.
Q	Slate Boot.
R	" Elevator.
S	Chutes for taking Slate to Slate cars.
T	Slate cars to take Slate to Dump.
U	Settling Tank.
V	Centrifugal Pump.
W	Coal Smudge Elevator.
X	Bin and Chute for Nut Coal.

DESCRIPTION.

The coal is drawn up the mine slopes by wire rope haulage, to the top of a wooden trestle some 50 ft. high, where it is dumped into a storage bin *C*, constructed with the purpose of enabling a regular feed, an essential requirement for good washing. From here it is taken by means of a bucket elevator *D* of special design, with automatic feed arrangement, and discharged on a double shaking screen *E*, which separates it into 3 sizes. The top screen being 1½″ mesh, the lump and nut coal pass over it, and are carried by two picking bands *F* and *G*, where the slate is hand picked by boys, to the single shaking screen *H* of 3″ mesh, which separates the coal into lump and nut. The nut coal drops through the screen *H* into a bin *X* and is carried by a chute to the cars. The lump coal passes over the screen *H* to lump loader *I* which lowers it to the cars. The lump loader consists of a horizontal part, and an inclined, swinging arm, the end of which can be raised as the work of loading proceeds, so that the fall of the coal and consequently the breakage is reduced to a minimum.

The coal which passes through the top screen of 1½″ mesh of the double shaking screen *E*, drops on a screen of ⅝″ mesh. The material too large to

pass through this screen drops into the crusher L, and after being crushed, is again elevated and discharged on the $\frac{5}{8}''$ mesh screen. The material passing through the $\frac{5}{8}''$ mesh screen drops into a screen drum J, which separates it into 3 sizes, which are carried by water in gutters to the jigs K_1 to K_{11}. These eleven two-compartment fine corn coal jigs are especially adapted for the sizes which they are to wash. In the jigs the raw coal enter at one end, moves across both compartments, and out at the other end as the washed product. In moving across, the slate, pyrites, barytes, and all other heavier particles, find their way down through the bed to the bottom of the jig and flow out through the slate valve in a constant stream.

The washed coal is taken to the boots O_1 and O_2, and the washed out slate to the boot Q, by means of gutters. The washed coal is taken by means of slowly moving perforated bucket elevators N_1 and N_2 to drain off the water, and dumped on the conveyor P which takes it to the storage tower. The slate elevator R discharges into the slate chute S from which small cars are filled, that are pushed to the slate dump by the picking boys.

The amount of water used in this plant is very small, as the same water is used over and over again, only the amount absorbed by the coal being replaced. By allowing the water to flow through a settling tank U, tolerably clear water is obtained, and the smudge or finer particles of coal are saved. These are elevated by means of a perforated bucket elevator W and discharged on the washed coal elevator N. From the settling tank the water flows back to the centrifugal pump V which again forces it to the jigs, etc.

The capacity of the washing plant is 500 tons in 10 hours.

The machinery was all built into the old trestle work and tipple. A better arrangement could have been made, had a separate building been put up for the washing plant.

THE DIESCHER COAL WASHER.

The Diescher plant may be constructed with one box, as shown in Figs. 19, 20, 21 and 22, or with a number of boxes connecting with each other and worked by the same shaft. The boxes may either have outlets, as shown in section by Fig. 20 and on plan Fig. 21, with an elevator for carrying away the slate and other deleterious materials, or where the boxes are fixed on elevated ground they may have pyramidal receptacles into which such material falls and is discharged at intervals by its own gravity through a valve operated by a lever.

Its modus operandi is as follows: The coal is dumped from the back upon the screen, shown in section by Figs. 19 and 20; the water is conveyed to the washer by a 3-inch pipe entering into a cast iron box fixed at the back (see Fig. 21); this box runs along the back of the washer below the screen and delivers the water through four 2-inch holes cut out of the washer side (see Figs. 19 and 21). The action of the plunger forces the

water through the screen, agitating the coal on same and carrying the cleaned coal over the wooden ledge, shown to the left, and a little above the screen, into a trough which conveys it into bins; the slate and other heavy and deleterious materials, by force of their greater specific gravity, fall to the screen and escape, through the valve shown, into the discharge pipe and elevator, or into the box previously referred to.

The washer is constructed as shown by the respective figures, having 2 cast iron stanchions of H section footed out at the bottom as shown. The upper part of the stanchion has 9-inch web with 4-inch flanges, by about $\frac{7}{8}$-inch metal. The stanchions are connected together on top by means of 2 girders of similar section but arch backed, having the central part of top flange level and dovetailed to receive the bearing for main shaft. The stanchions are kept rigid by means of two $1\frac{1}{4}$-inch wrought iron tie bolts and distance pieces of pipe, (see top of stanchion, Fig. 20), and the girders are bolted to ends of stanchion by 4 wrought iron bolts at each end.

The body of the washer is composed of 4-inch white pine timbers of the widths shown, planed, tongued, and grooved. The side timbers project beyond the stanchions as shown in Figs. 19 and 21, the ends being let into same and further secured by an angle plate 4 inches by 4 inches, (see Fig. 23). It will be noticed by reference to Fig. 19 that only one end plate is shown. This is on account of there being a series of connected boxes in a line, the water communicating from one box to the other. The partitions of the boxes are also of 4-inch timbers reaching down to the angle of box as shown by Fig. 19. Between the partitions and end it will be noticed there is a space 8 inches wide right under the stanchions (see Fig. 19); this is the equilibrium chamber, and is provided to keep the water level and prevent a vacuum being formed. Within the partition there is a lining (which can easily be renewed) which serves to confine the water between the plunger and the screen. Above the plunger an angle iron frame 4″ x4″ x½″ is fixed as shown in Figs. 19 and 20, upon which the wooden frame, to which the screen is connected, rests; this angle iron, together with the screen, is not fixed perfectly level but is inclined 1 inch towards the slate valve to facilitate the discharge of the coal and slate through their respective openings.

FIG. 19.--LONGITUDINAL SECTION.

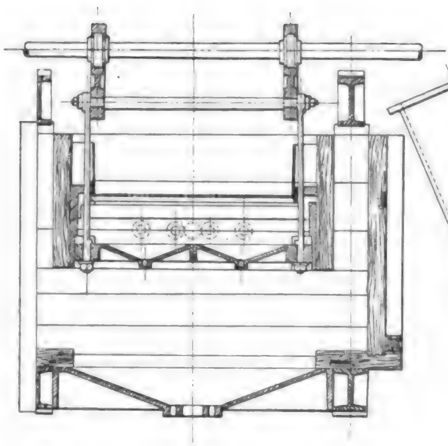
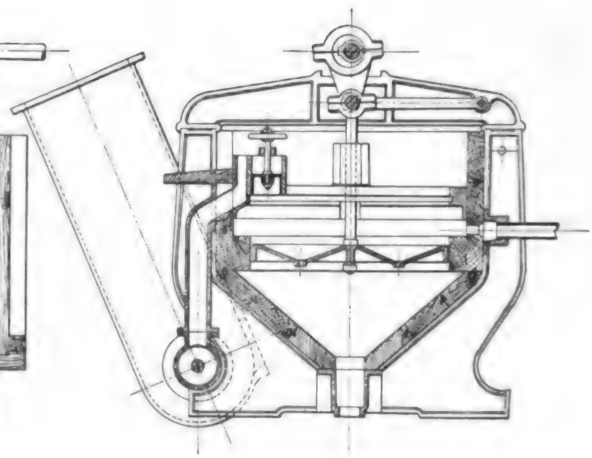


FIG. 20.—TRANSVERSE SECTION.



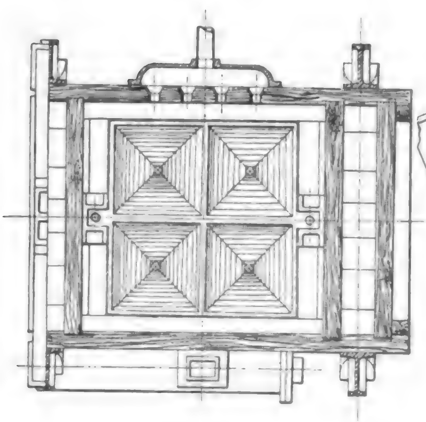


FIG. 21.—PLAN.

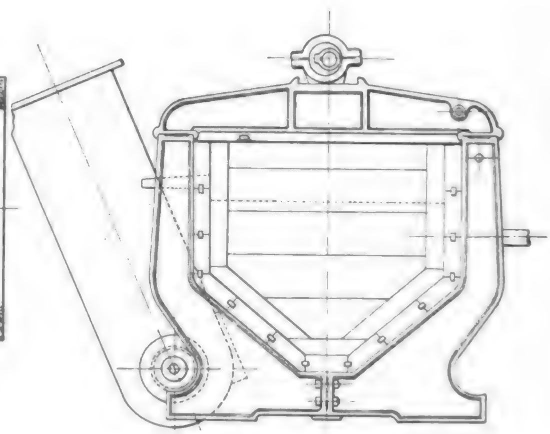


FIG. 22.—END ELEVATION.

DIESCHER COAL WASHING PLANT.

The plunger is of cast iron, $\frac{3}{4}$ inch metal, 5 feet long by 4 feet 3 inches wide, with four buckled surfaces as shown in Figs. 19, 20 and 21, in the center of each of which is a small hole to allow the discharge into the lower chamber of any fine material which may fall through the screen. The plungers are suspended by two rods of suitable size as shown by Figs. 19, 20 and 21, which are secured to plunger casting by means of collars and nuts, the casting being specially thickened for the purpose (see Fig. 19). The suspension rods connect with a cross-bar as shown by Fig. 19, and are shielded from the coal by two castings (see Fig. 20), having openings $4\frac{3}{4}$ inches by 5 inches, by 7 inches deep. These castings are connected to the washer by lag screws. The plunger has a stroke according to material operated upon, ranging from $1\frac{1}{2}$ inch to 2 inches, the smaller stroke being most suitable for

fine material. The 3-inch cross shaft is suspended from eccentric or main driving shaft by means of two cast iron eccentric yokes as shown by Figs. 19 and 20. The yokes are steadied by a rod as shown on Fig. 20. The eccentric or main shaft is 3½ inches in diameter. It turns in bronze bearings, resting on the girders previously referred to, and is generally driven by a 32-inch pulley, making 70 to 80 revolutions per minute, according to the stroke of plunger and the material operated upon. Where there are several boxes the plungers rise and fall alternately, thereby balancing each other, and keeping the water beneath them in equilibrium. The screens of the boxes are invariably four feet square, composed of a rigid wrought iron frame, carrying wires of spring brass, which are placed parallel and in the direction of the discharge, having a space between of about 1-64 of an inch. These wires are fastened to the frame by means of copper wires, and all of the joints are protected by solder. It will readily be seen that this arrangement secures a screen, strong, rigid and durable, and which allows free passage to the water and to the finest pyrites only.

The slate valve is fixed in the position shown by Fig. 20; the body of the valve has an opening on both sides, 6 inches by 2 inches, the area of which can be modified at will by means of the movable valve within, which is operated by a hand wheel and screw. The size of the discharge pipe from same (see Fig. 20) varies with the kind of material operated upon.

At the bottom of washer a casting is secured as shown by Figs. 19 and 20, having a valve in the center for the discharge of the fine pyrites or of the water when necessary. Access is provided to the under side of plunger by means of a circular man hole, about 14 inches in diameter, having a cast iron arched door and frame.

The correctness of the principles involved in the construction of the Diescher washer is noticeable in several ways. One of its good points is that the position of the plunger is directly under the screen, which produces a uniform and energetic action of the water and an equal operation all over the screen surface, whereas when the plunger is at the back an unequal action of the water is produced on the screen, the effect of which is sometimes only partially obviated in other machines by means of aprons and scrapers.

Another advantage of this machine is the method provided for introducing the water which enters the upper chamber between the screen and the plunger, as previously stated. The result of this is, as has been found in practice, that no valves are necessary in the plunger, although these are put in when specially desired.

The washing capacity of a single box varies according to circumstances, from 75 tons of coal up to 200 tons in 10 hours, according to the amount of dirt and pyrites mixed with it.

The cost of washing coal with the Diescher jig varies with the size of the plant and numerous other conditions. One man can attend to several

boxes as easily as to a single box washer. Even in the most unfavorable circumstances, the cost of washing the coal will be only a small fraction of one cent per bushel. In some cases the cost is less than 1-10 cent per bushel.

These Diescher machines have been in practical use for ten years, and are now to be found in all parts of the United States and even in Mexico. Their reputation for simplicity, durability, great capacity, and for excellence

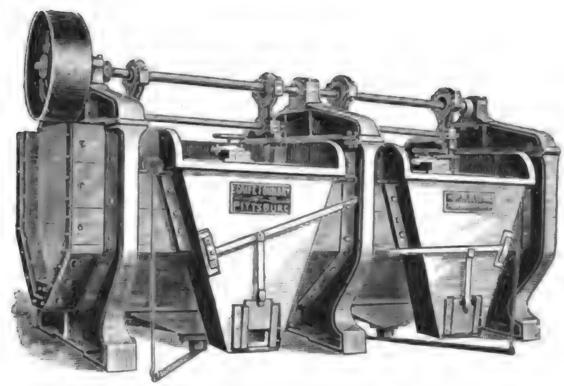


FIG. 23.—DOUBLE DIESCHER WASHER.

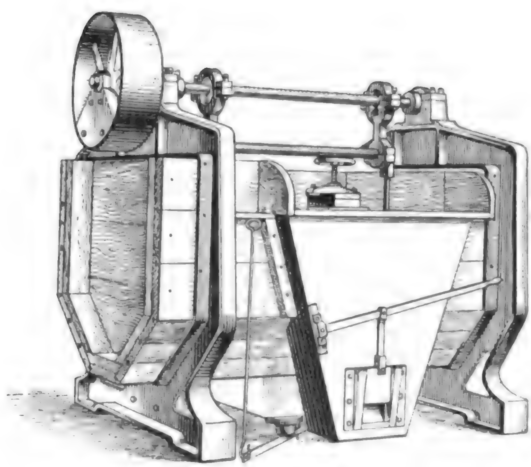


FIG. 24.—SINGLE DIESCHER WASHER.

and economy of the washed coal makes them very popular and in constantly increasing demand.

They are manufactured by the Scaife Foundry and Machine Company, Limited, of Pittsburgh, Pa.*

* From "The Colliery Engineer and Metal Miner" and "The American Manufacturer."

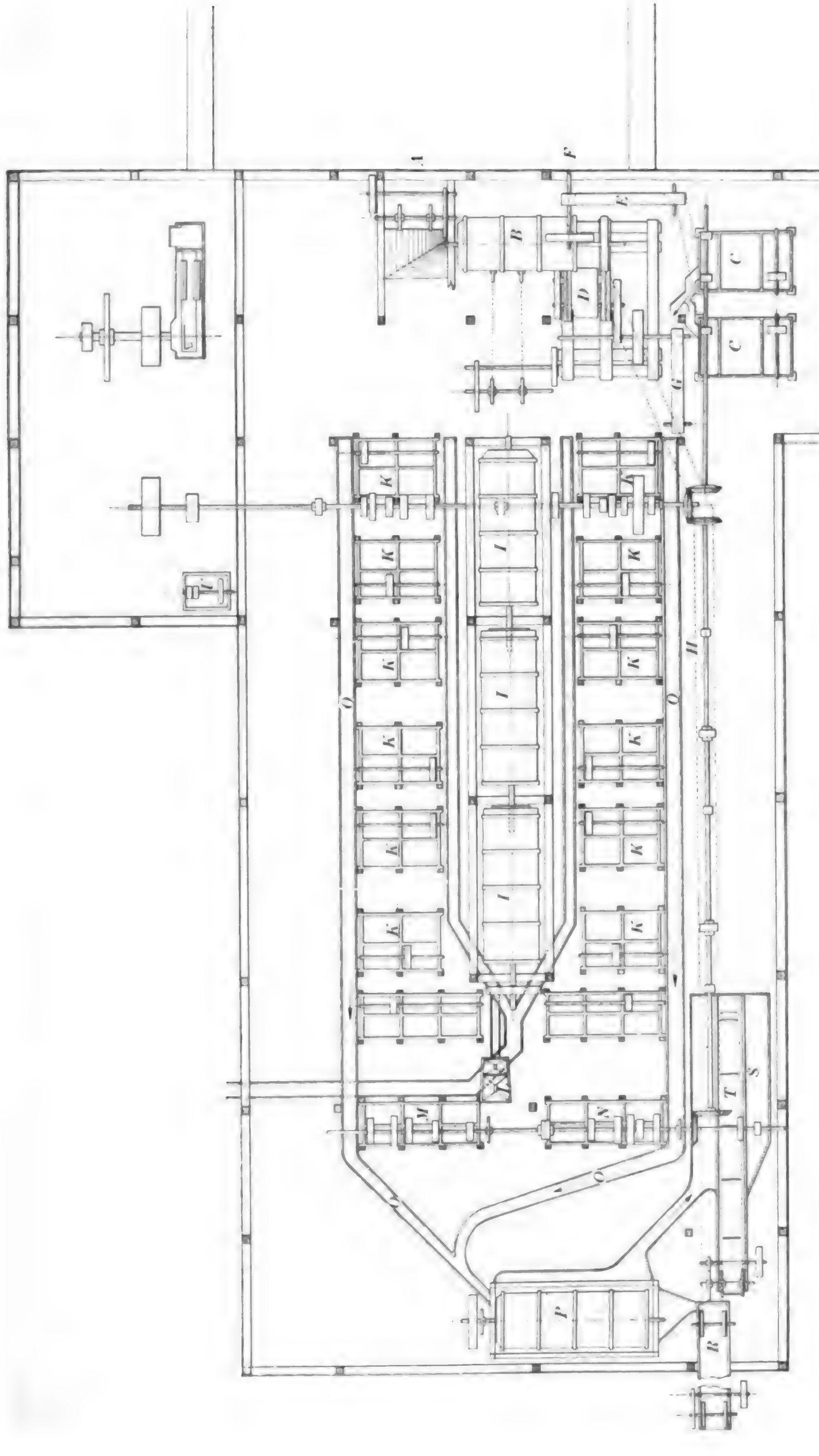


FIG. 25.—WALBURN-SWENSON WASHER. BUILT FOR COAHUILA COAL CO.—PLAN.

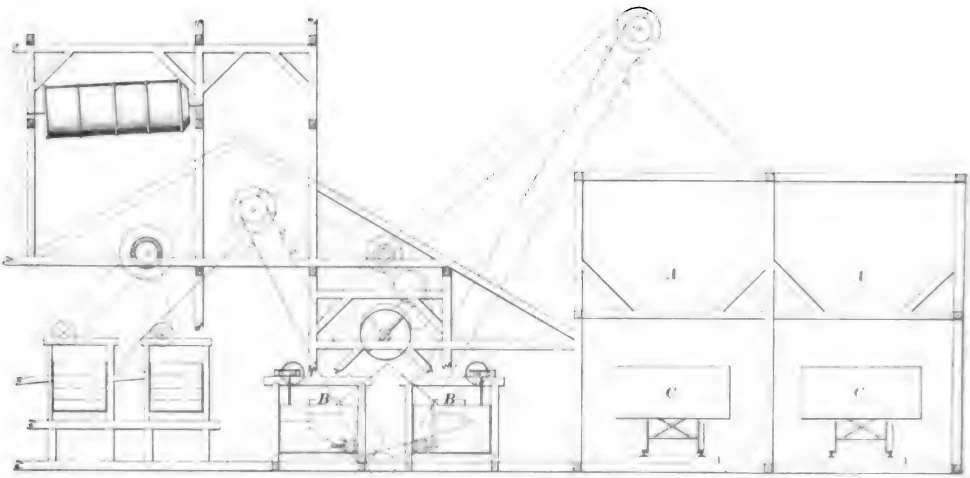


FIG. 26.—WALBURN-SWENSON WASHER, COAHUILA COAL CO.—LONGITUDINAL SECTION.

THE WALBURN-SWENSON WASHER.

I am indebted to Mr. E. G. Tuttle, E. M., Superintendent of the Coahuila Coal Company, Mexico, for the following plan and description of the washing operations at Hondo.

This is especially interesting, from the peculiar difficulty of removing soft interleaved impurities in the coal. The machinery is after the design of the Walburn-Swenson Company, of Chicago.

The coal from the mines is screened over diamond-shaped bars 1½″ apart. The screened coal is hand-picked, and loaded directly for shipment. The screenings drop into a hopper resting on a weighing platform attached to scales connected with a tipple platform.

The hopper is of 5 tons capacity. Each mine car of 1 ton capacity yields 500 lbs. of screenings.

Twenty-nine cars are dumped to fill hopper, the contents of which are then weighed and discharged by gate opened and closed by brake wheel operated from tipple platform.

From the weighing hopper the 1½″ screenings pass by a chute to the washer plant. An iron gate at bottom of pit working in slides and raised or lowered by a ratchet and pinion, operated from top of pit, regulates the feeding of the buckets of the raw screenings elevator *A*, by which the coal is lifted to a revolving screen *B*, covered with 35 mm perforated sheet iron.

This screen is 4 feet diameter and 8½ feet long in three sections. To each section there are 4 sheets of No. 8 iron, each 32″ x 39″. All coal larger than 35 mm passes to 35 mm to 50 mm nut jigs *C*. If coal larger than 50 mm is to be treated, what passes out of 35 mm screen can be screened again over a flat screen, so that only 35 mm to 50 mm coal passes to nut jigs. All larger than this can be passed to crushing rolls *D*, and re-

duced to size desired and dropped into washer pit to be again handled by raw screenings elevator *A*.

The washed coal from 35 mm to 50 mm jigs is hoisted by the nut coal elevator *E* to the top of the building at front, and from here can be chuted either to washed nut bins for shipment, by chute *F*, or to the rear elevator supplying bins with washed coal for charging coke ovens, through chute *H*.

The slate from nut coal jigs is hoisted by the nut slate elevator *G*, and chuted outside of the building, where it is handled to the waste pile.

The coal passing through the 35 mm screen passes to the elevator lifting the 0 mm to 35 mm coal to the top screen, where it is dumped into a hopper and fed into the first of the line of three elevated revolving screens, *I*, *I*, *I*.

These screens are 4 feet in diameter and 11 feet long of four sections each. These are covered with perforated sheets.

As the coal passes through the system of screens, a spray of fresh water is fed onto the top of each screen, to free any clinging particles and cleanse the screens. This water dropping through the screens with all coal smaller than the perforations falls into an inclined iron gutter or channel. The coal is thus carried from screen to screen until the point is reached at which the proper sizing is attained, when each size is drawn off with whatever water it contains, to its respective jig *K*, for jigging.

Each jig is supplied with a hydrant which furnishes whatever water is needed in addition to the water spouted with the coal from the screens to the various jigs.

The smallest screen is 5 mm, and all coal from 0 mm to 5 mm, with accumulated water, passes to classifier *L*, and is divided into two parts, each passing to a fine jig, being sized to about 0 mm to 2 mm (*M*) and 2 mm to 5 mm (*N*) respectively.

The washed coal, after passing from the jigs, enters a sluice box *OO*, and is carried to a revolving drainage screen *P*, perforated with 1 mm holes. The coal larger than 1 mm, with all water removed, passes out at end of screen and drops into the boot of an elevator *R*, which raises the coal to bin supplying washed coal to coke ovens.

The water and fine coal less than 1 mm filtering from drainage screen, flows to a settling tank *S*, in which a slow-moving drag *T* operates, that carries the settlings along a wide channel, which gradually raises from a level to a slight incline, until the settlings are raised high enough so as to be discharged at the upper end, where they drop into the elevator boot with the large washed coal for coking.

All waste water overflowing from settling tank is carried to pit in engine room, from which it is lifted by a centrifugal pump *U*, through a three-inch pipe to a launder box, running over the entire length of the jigs and supplying them with water.

The two 35 mm to 50 mm jigs *C*, have each a single bed 2′ 3″ x 4

grate bars 5/8″ wide and 7/8″ apart from the bed. A geared 4″ stroke is obtained in a second compartment by means of a slide yoke.

Of the remaining jigs, 12 are of double compartments, with 2 beds each 24″ x 32″, and 4 jigs are of 3 compartments with 3 beds each 18″ x 32″, for treating fines. Each bed has an adjustable slate discharge.

The various strokes for obtaining the proper separation of the different sizes of coal and slate are produced by a wooden plunger attached to an adjustable cam and eccentric which can be adjusted to give a stroke from 1/4″ to 2 3/4″.

The jig beds of the jigs are made of a wooden frame or lattice work with 2″ square openings forming a support for copper cloth of mesh varying from No. 6 to 10.

The analyses of the coal, washed coal and coke are as follows:

	Raw Screening.	Washed Coal.	Coke.	Slate from Waste Box.
Moisture	1.40	0.79	0.43	2.22
Volatile Combustible Matter	19.79	20.80	1.89	15.76
Fixed Carbon	60.25	66.80	83.47	30.96
Ash	17.83	11.61	14.24	50.12
Sulphur	.85	0.51	.82	.93
Phosphorus	....	....	.019	....

The washed coal is run from the washed coal bins into a standard charging larry, and then to coke ovens.

The plant consists of 100 Bee-Hive ovens, 12 feet in diameter and 6 feet high.

The coke produced is of 48 and 72 hours' burning. The charge being 4 1/2 tons of coal, yielding 2 1/2 tons of coke.

The cost of this plant is given as follows:

Grading	$300.00	Mexican.
Foundations	1,375.00	"
Buildings	2,500.00	"
Machinery	13,000.00	"
Erecting Machinery	4,600.00	"
Total	$21,775.00	"

The cost of washing is about 30 cents per ton in American or United States money. This large cost is caused by two elements, the extreme difficulty of separating the soft interleaved slates from the coal and the inefficient labor of this part of Mexico.

The accompanying drawings will show the operations of this washing plant in full details.

Fig. 25 gives the general arrangement of the several parts of this washing plant, with auxiliary appliances.

Fig. 26 shows the longitudinal section of this coal washer, with its elevators, receiving bins, coal cars, etc., etc.

THE ROBINSON COAL WASHER.

The Robinson Coal Washing Machine is illustrated and described as follows:—(See Fig. 27.)

The Washer consists of a wrought-iron receptacle, the shape of an inverted cone *O*, surrounded by a jacket at the bottom, communication being made by a number of perforations by which water at considerable pressure is admitted into the cone. A vertical shaft, having keyed upon it four revolving arms or agitators, *P*, occupies the higher parts and sides of the cone; this part of the machine is kept in motion by a small engine of say 10 inches diameter cylinder fixed at *K*. The water supply *B*, from the cistern *A*, to the cone through the water chamber is regulated by a valve. A supply of coal is admitted from the small coal apparatus down the slide or spout *E*, into the open top of the cone filled with water, the revolving or stirring motion being kept up by the agitators, and the upward flow of water being continuous; the result is that the stone and rubbish from the coal falls into a chamber. At this point two slides connected to necessary levers are inserted, the bottom one being closed and the top one opened during the operation of washing. To discharge the rubbish it is necessary to shut the top slide and open the bottom, and the rubbish falls into a truck below. The clean coal at the top passes down a sieve into a hopper *J*, and thence into another truck below beside the rubbish truck, at will. Immediately below the sieve mentioned is fixed a collecting tank into which the water is drained off from the washed coal and forced by means of a pulsometer *F* into the supply cistern *A*. An overflow pipe *C* is arranged between these two cisterns to prevent waste of water in case of the pulsometer filling the top cistern *A*.

It is estimated that the cost of all machinery complete, for a washer cleansing 300 tons of coal per day, will not exceed $1,900. To this must be added the cost of erection and the timber work, say $1,100—making in all $3,000.

The following analyses are submitted to show its work in coal washing:

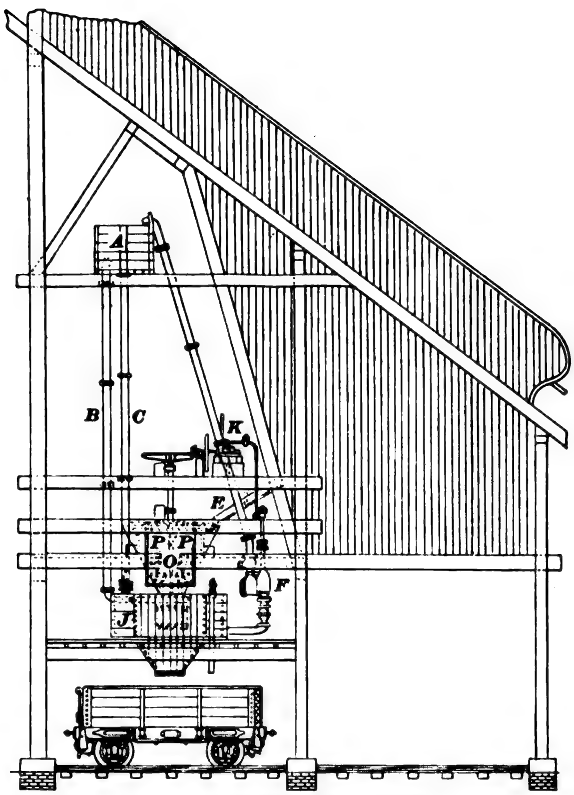


Fig. 27.—ROBINSON WASHER.

	BLACK BOY. (Screenings.)		AUCKLAND PARK. (Screenings.)	
	Unwashed.	Washed.	Unwashed.	Washed.
Ash	11.30	3.84	9.85	4.60
Sulphur	2.08	1.46	1.18	0.86

	AUCKLAND PARK. (Screenings.)		WESTERTON. (Screenings.)	
	Unwashed.	Washed.	Unwashed.	Washed.
Ash	5.95	3.60	10.10	5 70
Sulphur	1.08	1.00	1.61	1.18

	WEST AUCKLAND. (Small Coal.)		ST. HELENS. (Small Coal.)	
	Unwashed.	Washed.	Unwashed.	Washed.
Ash	15.40	3.70	11.10	2.82
Sulphur	1.14	0.76	1.92	1.16

	NEW COPLEY. (Dusty Coal.)		NEW COPLYE. (Coarse – Small.)	
	Unwashed.	Washed.	Unwashed.	Washed.
Ash	11.28	3.83	14.75	2.74
Sulphur	1.50	0.84	1.61	0.78

W. F. K. Stock, Chemist.

In kindly furnishing the foregoing information in regard to this coal washing machine, Mr. H. S. Chamberlain, President of Roane Iron Company of Chattanooga, Tennessee, writes: "I came across this machine in 1890, while on a trip in the north of England, and was so struck with its simplicity and effectiveness that, after considerable negotiations, I secured the agency for the machine in this country, and put one up at our colliery at Rockwood, Tennessee.

"The simplicity and effectiveness of the machine is something wonderful; it only requires one laboring man to attend to the machine, and I should say two cents per ton would be the full expense in washing coal.

"The calculation is made on ten hours' work per day; that is, a 400-ton machine will wash 400 tons of coal in ten hours, but really will do twenty-five per cent. more if pushed very little."

In the foregoing description of the work of this coal washing machine, it is understood that the coal used is the "screenings" made at the coal mine, in preparing the several classes of lump, egg and nut coal for market.

If the "run of mine" coal is used for the manufacture of coke, it will require the preparatory processes of disintegration and washing.

THE LÜHRIG WASHER, DOWLAIS, WALES.

Figs. 28, 29 and 30 with the sectional view of Shaft Head Frame and Washer will convey the general arrangements adopted at the Rybnik Collieries in the location of the Lührig coal washer in connection with the coal mine and coke ovens at that place.

This plan is interesting, as it illustrates the method of constructing these works to secure the most economy in the several operations. The processes essentially consist in receiving from the mine, on the platform or landing of the colliery shaft, the "run of mine" coal. It is then passed over a three-inch screen, the large lumps going to market, the screenings being deposited for further treatment in the washing section of the plant. This slack or fine coal is then classified by revolving screens and washed in the usual way.

Large settling tanks are provided for the very fine sludge coal, which is usually found valuable in the manufacture of coke.

Automatic arrangements have been made for storing the washed coal, so as to permit it becoming somewhat dried before charging into the coke ovens.

The plan also provides for the direct and economical handling of the coal from the mine until it is loaded into railroad cars for market or placed in the washer for the coke ovens.

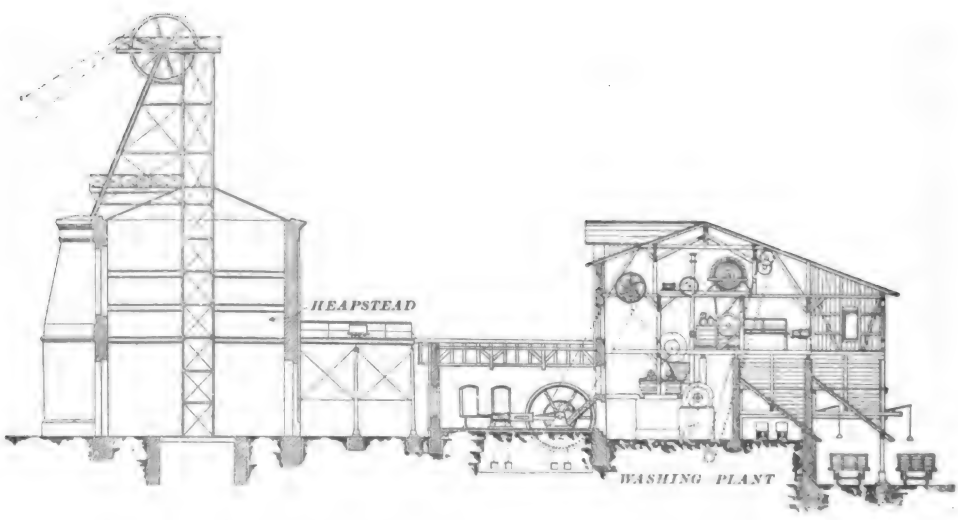
This, in common with other washing machines, will require special arrangements to meet local conditions of coals to be treated.

It is claimed that by this process the washed coal will not contain over four per cent. of ash at most, and that the tailings or refuse will retain only three per cent. of coal.

The cost of washing alone is given at 1½ penny; in the United States the cost would be 6 to 7 cents.

The capacity of this washer can be enlarged to meet the largest demands on its output.

Prof. C. Kreicher, of the Royal School of Mines, Freiberg, is quoted as having approved of this method of coal washing.



SECTIONAL VIEW OF LÜHRIG WASHER AND SHAFT HEAD FRAME, AT DOWLAIS.

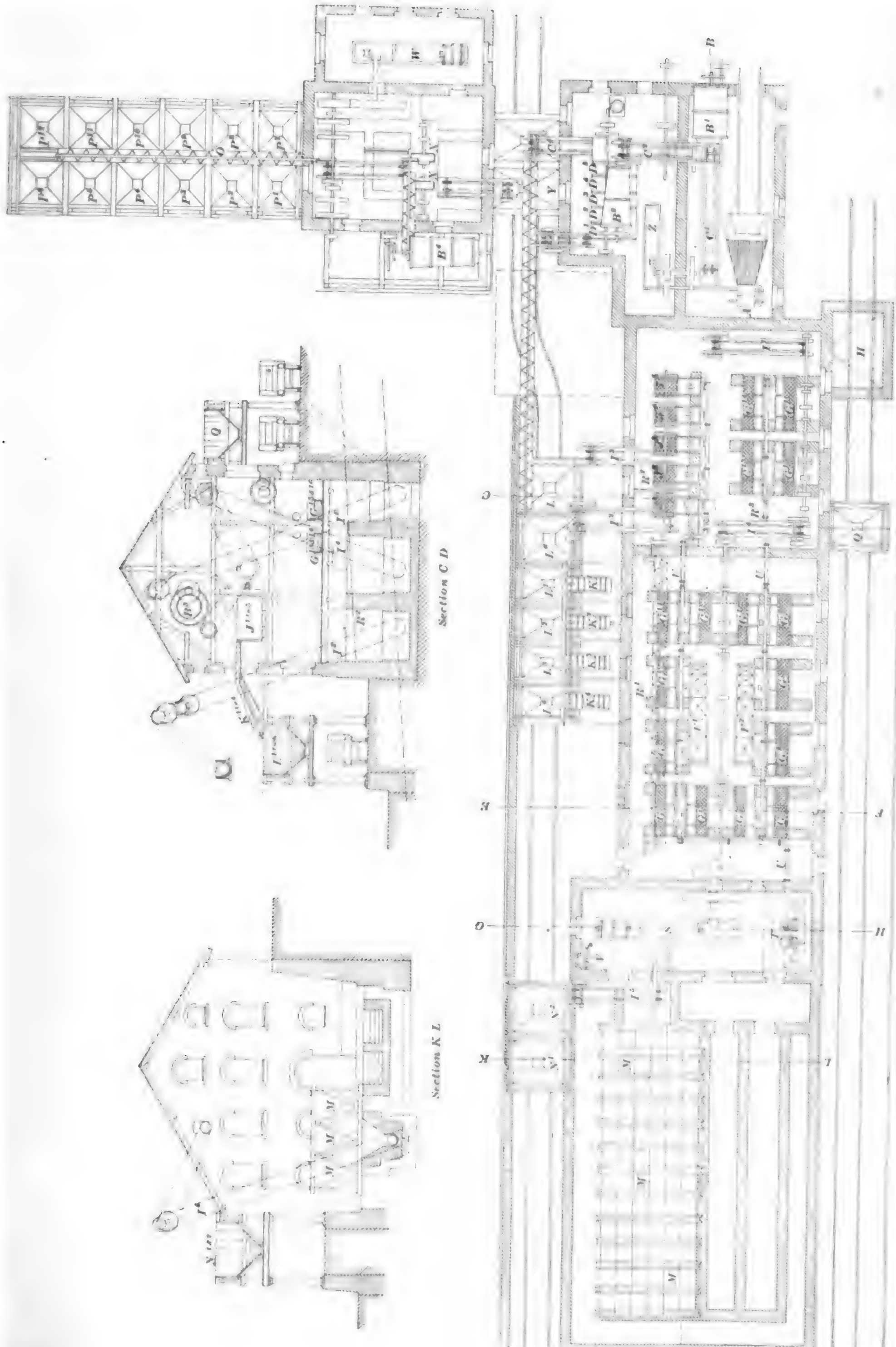


FIG. 23.

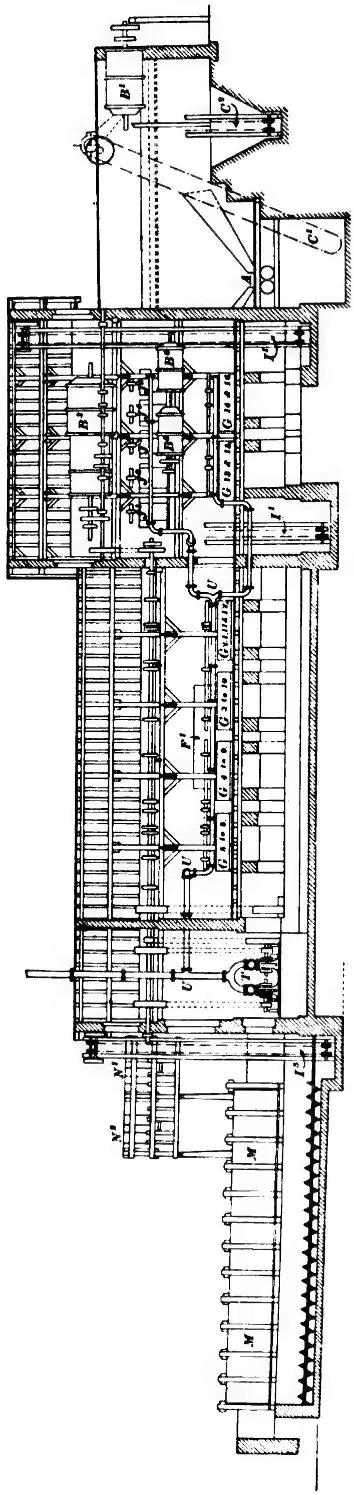


FIG. 29.—SECTION ON LINE *A B* OF FIG. 28.

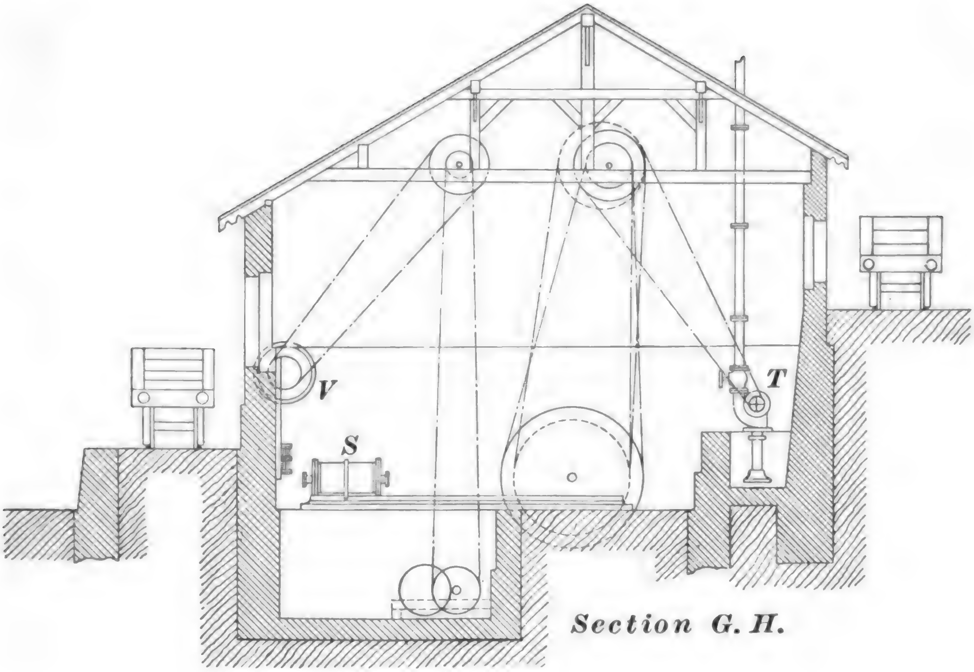


FIG. 30.

THE DOWLAIS WASHING ARRANGEMENT.*

This arrangement has been rendered more complicated owing to the machinery having to be erected on a long narrow strip of ground, divided by an incline which had to be arched over, and also by provision having to be made for washing bituminous and steam coal separately.

The arrangement therefore comprises two sets of plant, viz.: –

(*a.*) The washing system for bituminous coals.

(*b.*) The washing system for steam coals.

(*a.*) THE SYSTEM FOR WASHING BITUMINOUS COALS.—The bituminous coal is brought to the Shephard machine, which existed previous to the erection of the new washing machine, where it is crushed by means of rolls *A* (Figs. 28 and 29). It is then elevated by the elevator C^1 into a revolving screen B^1, which divides it into two sizes, viz., from $\frac{3}{8}$ inch to 0, and from $\frac{3}{8}$ inch upwards.

The nut coal, from $\frac{3}{8}$ inch upwards, is raised by means of another elevator C^2, into a second revolving screen B^2, placed above the Shephard washing machines $D^{1 \text{ to } 5}$. This screen divides the coal into five sizes, which are washed each in a separate machine of Shephard's. After washing, the nut coal is raised by an elevator C^3, into bunkers *Y*, situated between

* Extracts from paper read by MR. R. DE SOLDENHOFF to the South Wales Institute of Engineers in 1884 and 1885.

the building of the Shepard machines and the building of the crushers. From these bunkers the bituminous nut coals may be discharged into wagons, when required.

The fine bituminous coal, from $\frac{3}{8}$ inch downwards is transported by a current of water along a trough to a revolving screen B^6, situated in the building of the new washing machines erected by Messrs. Evence Coppée & Co., Engineers, Cardiff. This screen divides the coal into two sizes, from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch, from 0 to $\frac{1}{4}$ inch.

The coal from $\frac{1}{4}$ to $\frac{3}{8}$ inch is washed in two feldspar machines, $G^{14\ \&\ 16}$ (Figs. 28, 29 and 30), placed immediately below the screen; and the coal from 0 to $\frac{1}{4}$ inch is conveyed in a trough by a current of water to the pointed trough F^2, shown on the plan, and situated in the adjoining room of the new building. It is here divided into six sizes, each of which is washed separately in the feldspar machines $G^{1\ \text{to}\ 6}$, placed next to the pointed trough. The $\frac{3}{8}$ inch and upwards bituminous coal is sent from the elevator raising the washed coal into a crusher. After being crushed it meets the small steam coal in a bunker situated below the crusher, from which an elevator raises the coals, already partly mixed, to a screw placed on the bunkers erected in front of the crushing department. The screw O, finally mixes the two coals and distributes them into bunkers $L^{5\ \&\ 6}$, from which ultimately the small mixed coal is taken to the coke ovens.

(*b.*) Washing System for Steam Coal.—The steam coal is also treated in the new washing arrangement. Arriving in wagons, it is tipped into a bunker H, in front of the new building (Figs. 28, 29 and 30), from whence an elevator I^1, raises it into a large revolving screen B^3. This screen divides the coal into six sizes, one of which is 0 to $\frac{3}{8}$ inch, and five others varying from $1\frac{3}{4}$ inches to $\frac{3}{8}$ inch. The last five sizes are each washed separately in five machines $J^{1\ \text{to}\ 5}$, ranged on the second floor, from whence the coal is run off onto reciprocating screens $K^{1\ \text{to}\ 4}$, for the purpose of draining off the water. The dry coal drops into bunkers $L^{1\ \text{to}\ 4}$, from whence it may be sent away in railway wagons.

When, however, the five sizes are required for coking, the coal is sent by a trough into a revolving screen B^4, fixed next to the crushers, from whence it is taken in a dry state, by means of a screw, to the disintegrators X. The water draining off, and which contains small coal in suspension, coming from the drying revolving screen and the reciprocating tables, returns to the feldspar machines.

The fine coal from 0 to $\frac{3}{8}$ inch, from the large revolving screen B^3, enters first into another revolving screen B^5, which divides it into two sizes, $\frac{3}{8}$ inch to $\frac{1}{4}$ inch and $\frac{1}{4}$ inch to 0. The first size is washed in two feldspar machines $G^{13\ \&\ 15}$, situated in the large revolving screen building, while the second and smallest is carried by water in a trough to a pointed trough F^1, similar to that used for dividing the bituminous coal. The pointed trough divides the coal into six sizes, each of which is washed in separate

machines $G^{7 \text{ to } 12}$. All the fine washed coal in a feldspar machine runs together into a large basin, from whence an elevator I^4, with perforated buckets, raises it to the top of the bunker Q. The small coal may be bunkered if desired; if not it may be sent by a transporter to the crushing building, where it is re-mixed with the crushed bituminous and steam coal.

The overflow of small coal from the small coal basin runs first into a long trough provided with a screw, and, as the small coal settles, the screw brings back the coal to the common small coal basin, whilst the water runs into settling tanks or clarifiers *MM*.

The clarifiers *MM*, are three long pointed troughs, provided with a screw situated underneath.

The dirty water, after having passed through the clarifiers, returns to the well of the centrifugal pump *T*, by which it is sent back and redistributed to the washers.

The mud, settling in the clarifiers, drops by gravity into the trough of the screw, which transports it to the elevator I^5, situated at one end of the clarifiers, which raises the mud and drops it into bunkers $N^{1 \& 2}$.

The arrangement as described above is washing 100 tons of coal per hour.

REFERENCE TO THE DOWLAIS WASHING ARRANGEMENTS.

A Crushing Rolls.
B^1 Revolving Screen for Bituminous Coal, 0″ and $\frac{3}{8}$″.
B^2 " " " $\frac{3}{8}$″ and upwards.
B^3 " " Steam coal, 0″ to $\frac{3}{8}$″ and upwards.
$B^{5 \& 6}$ Small Revolving Screen for Fine Coal.
B^4 Revolving Screen for Drying Nuts for Coking.
$C^{1,2,3}$ Bituminous Coal Elevators.
$D^{1,2,3,4,5}$ Shephard's Washing Machines.
E Trough carrying Fine Coal to Screen B^5.
$F^{1 \& 2}$ Spitz-Kastens, for Classifying Fine Coal.
$G^{1 \text{ to } 6}$ Bashes for Fine Bituminous, from 0″ to $\frac{2}{8}$″ (Feldspar Cases).
$G^{14 \& 16}$ " " " $\frac{2}{8}$″ to $\frac{3}{8}$″ "
$G^{7 \text{ to } 12}$ Feldspar Bashes, for Fine Steam Coal, 0″ to $\frac{2}{8}$″.
$G^{13 \& 15}$ " " " $\frac{2}{8}$″ to $\frac{3}{8}$″.
H Basin receiving Dry Steam Coal from Wagons.
I^1 Elevator raising Steam Coal to Screen B^5.
I^2 " Mixed Coal to Transporter for Crushing.
I^3 " Shale.
I^4 " Interstratified Coal.
I^5 " Slimes from Clarificator.
$J^{1 \text{ to } 5}$ Machines for Washing Coarse Coal, $\frac{3}{8}$″ upwards.
K Reciprocating Screens.
$L^{1 \text{ to } 4}$ Bunkers for Washed Coal (Nuts).

$L^{5\&6}$ Bunkers for Fine Washed Coal, $\frac{3}{8}''$ and downwards.
M Clarificator, or Settling Tanks.
N Slimes Bunkers.
O Worm for Transporting Coal to $P^{1 \text{ to } 12}$ or to *X*.
$P^{1 \text{ to } 12}$ Bunkers for Crushed Washed Coal to Coppée Ovens.
Q Bunkers for Interstratified Coal.
$R^{1,2,3}$ Basins.
S Driving Engine for Washing Machines.
T Centrifugal Pump.
U Water Pipes for Supply to Bashes, &c.
V Small Engine for Driving Elevator and Worm of Clarifier.
W Disintegrator engine.
X Disintegrators.
Y Bunker for Washed Crushed Coal Delivery in Wagons.
Z Driving Engine.

REMARKS AS TO THE PROCESS OF WASHING, AND ITS RESULTS.

The important questions to consider in coal washing are, generally speaking, three:—First, to wash the coal clean, so as to remove all impurities, as far as that is possible; the second, not to allow any coal to pass away with the impurities; and the third, is to wash the coal cheaply.

As to the first point, which is a very important one, it would be reasonable to know the limit to which the impurity might be removed from the coal. We thought there was only one way of settling that question, and that was to ascertain, by analysis, the yield in ash of the pure coal, or the ash that could not be removed by mechanical means, as it was certain that even the purest picked coal would still contain a certain amount of impurities so intimately combined with the fuel that even with the best system of washing it would be impossible to remove it.

In order to estimate the ash thus intimately combined with the coal, the best way was to pick out small lumps (or "nuts") of pure coal, and submit them to analysis by incineration.

The method was so simple that it might be carried out by anyone with a little practice, even without any knowledge of chemistry, and would enable him to estimate the contents of the ash in pure picked specimens of coal—a result which might be taken as the absolute limit of the greatest amount of purity to be obtained by washing. Some coais were so pure that pieces would not show more than 1.5 per cent. of ash; others were so dirty that the ash amounted to 10 per cent. Fortunately, the last class of coal was scarce in this country.

The table here annexed shows the results of four months' coal washing in the washing machine erected at Dowlais, and described above:

TABLE.

Four Months' Results of Coal Washing in the Dowlais Washery.

	PERCENTAGE OF ASH IN WASHED COAL.																		PERCENTAGE OF ASH.				
	In Nut Coal Washers.					In Feldspar Washers, to Wash Coal Below ⅜ inch.																	
	Steam Coal.					Steam Coal.							Bituminous Coal.										
	1	2	3	4	5	6	7	8	9	10	11	12	6A	7A	8A	9A	10A	11A	12A	Unwashed Steam Coal.	Unwashed Bituminous Coal.	Mixture of Half Steam and Half Bituminous. Before Washing.	Mixture of Half Steam and Half Bituminous. After Washing.	In Coke made with the Mixture.
1884.																								
September and October .	5.7	4.9	4.5	5.4	5.4	3.9	4.5	4.3	4.5	4.1	3.9	4.0	5.3	5.9	6.8	5.9	5.8	5.2	5.3	18.2	20.8	......	5.9	......
November	3.7	3.8	3.4	4.3	3.6	3.5	3.8	3.6	4.9	3.3	3.1	3.5	......	5.2	5.9	6.2	5.5	4.7	4.9	15.6	25.0	......	5.8	10.7
December................	5.3	3.7	2.7	3.8	4.1	3.2	2.7	3.9	4.2	3.0	2.4	2.9	3.1	4.4	5.1	5.6	6.2	5.5	4.4	14.9	29.2	......	5.9	8.6
1885.																								
January	3.8	3.7	3.8	4.3	3.5	3.6	4.5	4.4	4.8	4.2	3.4	3.5	3.1	5.2	6.2	5.5	5.1	5.7	5.0	15.1	27.1	......	6.2	7.5
Average	4.6	4.2	3.6	4.4	4.1	3.5	3.8	4.0	4.6	3.6	3.2	3.4	3.8	5.1	6.0	5.8	5.6	5.2	4.9	15.9	25.0	20.4	5.9	8.9

In regard to the results of the Dowlais washing, as per details submitted in full in the foregoing table, I would simply refer to the average figures as typical of the results of the five months' work. The steam coal, in its unwashed condition, contained an average of 15.9 of ash, and the unwashed bituminous coal 25 per cent. of ash. The mixture of those two coals in the proportion of half and half gave an average of 20.4 per cent. of ash, and that mixed coal, after washing, contained 5.9 of ash, whilst the coke made with that mixture gave an average of 8.9 per cent. In the month of January the coke made with that mixture of washed coal gave only 7.5 per cent. of ash. Those might be considered as fair average figures. During the first three months after starting—viz., of September, October, and November, comprised in the table—the washing and sorting were not as perfect as in the subsequent months; I therefore took the figures of the month of January as being a fair statement of the result.

Now with respect to the second point that required consideration, viz., to conduct the operation so as not to remove any portion of the free coal with impurities or with the shale itself; and the best way to ascertain that the shale is practically free of coal, is by taking a sample of the shale washed out, dividing it into two parts, one part to be submitted to a careful washing in an ordinary washing basin in order to remove all the particles of coal from it, then the shale, after being dried, to be incinerated; in that case the difference between the weight of the ash and 100 will give the yield of volatile matters.

Now, taking the other sample of shale, and after drying and incinerating it, the difference between the weight of the ash and 100 will give the yield of volatile matters, and in plus the free coal contained by the shale.

Deducting the result of the incineration of the re-washed portion of shale from the last result of incineration, the difference will show the free coal carried away with the shale.

In the feldspar washery of the Coppée system the free coal in the shale varies from 1½ per cent. to 5 per cent. The yield in ash in shales varies not only from district to district, but from a seam of coal to a seam of coal. However, we may state that, according to many hundreds of analyses made by us of the shales of South Wales, the ash amounts in them to from 66 per cent. to 75 per cent.

Some Lancashire shales yield only about 47 per cent. of ash.

With reference to the third point under consideration, viz., the question of cost, it might be said that the cost of washing, including labor and all charges, except interest on capital, *does not exceed 3d. per ton of washed coal.*

To conclude this chapter we annex a few analyses of the Clifton and Kersley small coal in an unwashed state—analyses that were made previous to our erecting the washery:—

	Per Cent.	
The Cannel coal contained	30.34	of ash.
The Doc Mine coal contained	16.45	"
The pure picked Nuts of the Cannel coal contained	8.20	"
Whilst the pure picked Nuts of the Doc Mine coal contained	2.74	"
So that by mixing the two above coals in equal quantities the average ash in the mixture would amount to	23.395	"
Whilst the average of the intimately connected ash with the Nuts in the mixture of those in equal parts would amount to	5.470	"
After three months' washing, a few samples of small coal taken and analyzed gave in average	6.55	"

So that the washed coal differed from the absolutely pure coal by 1.08 per cent. of ash only, which may be considered an exceedingly satisfactory result.

In the presence of so many varieties of coal crushing and washing machines, evidently designed to meet the several wants in the treatment of the different qualities of coals, there can be no reasonable excuse for using slaty coals in the manufacture of coke.

This essential requirement of clean coke, in metallurgical operations, is still more imperative, when it is considered that the slates of the coal go over into the coke and carry with them the associated sulphur. In furnace operations, especially when slate in the coke is silicious, an increased charge of limestone will be required to eliminate these impurities, and this will make it further necessary to add to the fuel charge also. Besides all this there is the danger of the presence of the sulphur in the pig metal produced, if it is designed for the manufacture of steel.

It is therefore evident, that the only safe plan in the manufacture of coke for metallurgical uses, is, to use only a pure quality of coal, or in case this cannot be secured and a second quality must be used, then its cleansing, by crushing and washing, becomes an absolutely necessity.

In America, with its ample areas of the best qualities of coals, it is only necessary at this time to require clean mining to produce coal of great purity for manufactures and in the production of coke.

Recently at many of the coal mines in Europe, coal washing of fuel for manufacturing purposes in coming into very general favor, but in America, with its superior qualities of coals, it is only necessary to cleanse the secondary or slaty coals in preparation for the manufacture of coke.

CHAPTER IV.

THE INITIAL METHODS OF COKING, IN OPEN AIR OR PARTIALLY CLOSED OVENS.

Time of the Beginning of Coke Making not Clearly Established, about 1735–1750, in England.—The Exhaustion of Charcoal Timber Evidently Increased the Manufacture of Coke.—In United States, little, if any, Coke was made until after the Revolution.—In May, 1813, a *Coak* Expert appears in Pittsburgh.—In 1816-17, Col. Meason Introduces a Rolling Mill in Fayette Co.—With the Increasing Scarcity of Charcoal Timber, the Acting Committee of the Society of Pennsylvania sends W. Strickland to England in 1825, to Learn the Coking of Coal.—The Instructions given him are quite Comprehensive.—Some Record of the Use of Coke in the Alleghany Furnace, Blair Co., in 1811.—Mr. James M. Swank Suggests that in the Early Efforts in the Use of Coke, Charcoal was added as a Mixture, or that Coke was used in Mixture with Charcoal.—In 1835, a Premium Offered by the Franklin Institute of Philadelphia, for the Manufacture of Iron by Coke.—Mr. William Firmstone Secured the Reward by Coke made from Broad Top Coal.—In 1837, Coke Iron was Made at Fairchance, near Uniontown, Pa.—Early Efforts of Using Coke not very Satisfactory; evidently the Coke was badly Made.—In 1849, Prof. J. P. Lesley has no Record of a Single Coke Furnace in Blast in Pennsylvania.—In 1856, however, he Reports 21 Furnaces in Blast.—Early History of Coke Making in the Connellsville Region.—The Disastrous Effort in 1842 to Market it by Arks.—Connellsville's Excellent Coke Stimulates its Use.—It was a Struggle up to 1880.—This Year was the Great Period of Rapid Increase.—Table Showing the Increase of Coke Ovens.—Bee-Hive.—Number of Coke Ovens in United States in 1892.—Table Showing Production of the Several States and Territories in 1880 and 1892.—Table Exhibiting the Growth of the Manufacture of Coke in the United States 1880 to 1893.—Coal Areas of U. S. and Territories.—Manufacture of Coke in U. S. 1893.—Production of Coal and use for Coke in U. S. and Territories 1893.—The Era of Coke.—Consideration of Value of Fuels in Blast Furnace Use.—Excellent Coking Coals of United States.—From its Extensive Use, the Manufacture Requires Increased Care.—The Early Methods Considered.—The Art of Coking.—Early Methods of Coking.—Open Air Pits or Mounds.—Walled Ovens.—Partially closed Ovens.—Bee-Hive, Thomas, &c.—Work of Coking in Heaps or Mounds Wasteful.—Bee-Hive Oven and its Work.—Plan of Modern Bee-Hive Ovens.—Specifications for Construction of Ovens.—Process of Coking in Bee-Hive Ovens.—Careful Tests of Products in the Connellsville Region.—Analyses of Tests.—Experiments in Laboratory confirm Results.—The Thomas Oven and its Work.—The McLanahan Oven and its Results.—A More Recent Design by McLanahan; Oven with Pusher, &c.—The Durham English Bee-Hive Ovens.—Letter of Sir Isaac Lowthian Bell.—Also Letter from Engineer Steavenson on the Economy of Utilizing Heat from these Ovens.—Waste Heat Utilized in United States, by Mr. E. Ramsay, Engineer Tennessee Coal and Iron Co.—Plans of Same.

Authorities are not in harmony as to the time of the beginning of coke manufacture in England. In 1735 Darby is reported as using coke successfully at Coalbrookdale, in Shropshire. But little was accomplished, however, until 1750 when its use became extended as a blast furnace fuel.

Evidently the same economic conditions that subsequently expanded the use of coke in the United States of America, had their earlier force in England, from the scarcity of wood for making charcoal, with its increasing cost, urging iron manufacturers to search for and use a less expensive fuel.

Mr. Joseph D. Weeks calls attention to the fact, that from the abundance of wood for making charcoal in the United States, and the encouragement given to the exportation of charcoal metal to England, it is quite improbable that much, if any, coke was manufactured prior to the Revolution.

In May, 1813, an advertisement appeared in the Pittsburgh *Mercury*, indicating that John Beal, an English emigrant, who possessed the knowledge "of converting stone coal into *coak*," would, under certain conditions communicate the same "to proprietors of blast furnaces."

It is not on record whether this offer conduced to the introduction of the manufacture of coke in America.

Shortly after this, however, in 1816-17, Col. Isaac Meason built the first rolling mill, west of the Alleghany Mountains, to puddle iron and roll it into bars, in Fayette county, Pennsylvania. This mill went into operation in September, 1817.

Shortly after this time general attention was directed to the rapid disappearance of the forests of Pennsylvania, accompanied with the discovery of large deposits of coal, and pointing to the necessity of its manufacture into coke for use in the growing iron industry.

In 1825 the acting committee of the Pennsylvania Society for the Promotion of Internal Improvements, sent Mr. William Strickland to England, as their agent, to study various subjects relating to internal improvements, and to investigate the methods employed in the manufacture of iron.

His letter of instructions was as follows:

"Attempts of the most costly kind have been made to use the coal of the western part of our State in the production of iron. Furnaces have been constructed according to the plan said to be adopted in Wales and elsewhere; persons claiming experience in the business have been employed, but all has been unsuccessful. In large sections of our State ore of the finest quality. coal in the utmost abundance, limestone of the best kind, lie in immediate contiguity, and water power is within the shortest distance of these mines of future wealth.

"The prices which are obtained for iron on the western waters are double those of England, the demand is always greater than the supply, and thus nothing but knowledge of the art of using these rich possessions is wanted.

"We desire your attention to the following inquiries on the subject of the mauufacture of iron:

"1. What is the most approved and frequent process for coking coal, and what is the expense per ton or caldron?

"2. In what manner are the arrangements or buildings, if any, constructed for the coking of coal, obtaining drawings and profiles thereof?

"3. Are there different modes for coking coal; and if they have any difference in principle, what are they?

"4. In what manner are the most approved furnaces for the smelting of ore constructed? Drawings and sections of the same to accompany the information that may be obtained upon this inquiry."

Mr. Strickland reported intelligently, with full drawings, illustrating the methods of coke making and the construction of blast furnaces for using this new fuel.

As these investigations were completed in 1825, it is inferred that coke had been in use before this time. A paragraph in the history of Fayette county refers to the use of coke in the Alleghany furnace in Blair county in 1811.

Mr. James M. Swank suggests that the early efforts in the use of coke in blast furnaces were made in mixtures with charcoal.

In 1835 the Franklin Institute of Pennsylvania offered a premium of a gold medal to "the person who shall manufacture in the United States the greatest quantity of iron from the ore during the year, using no other fuel than bituminous coal or coke, the quantity to be not less than 20 tons.

In the year that this offer was made Mr. William Firmstone was successful in making good gray forge iron for about one month at the Mary Anne furnace, in Huntingdon county, Pennsylvania, with coke made from Broad Top coal.

In 1837 F. H. Oliphant made about 100 tons of coke iron at his Fairchance furnace, near Uniontown, Fayette county, Pennsylvania.

These early efforts in the use of coke in blast furnaces were not very successful. Probably this came from the imperfect methods of making coke and the insufficient blast to the furnace. The latter was, perhaps, the most retarding cause in the early efforts in smelting pig iron with coke.

In 1837 coke was successfully used in the Lonaconing furnace, Frostburg, Maryland.

While these experimental tests in the use of coke were carried forward in Pennsylvania and Maryland, other States were also making efforts in the same direction.

Coke did not come into use rapidly. In 1849 Prof. J. P. Lesley fails to record a single coke furnace in blast in Pennsylvania. In 1856, however, he reports 21 furnaces in blast in Pennsylvania and three in Maryland using coke.

The early history of coke making in the Connellsville region is involved in some obscurity; but Col. Meason used coke at his refinery in 1819.

In 1841 two carpenters, Provence McCormick and James Campbell,

united with a stone mason, a Mr. John Taylor, in a coking enterprise. The mason was to build the coke ovens, and the carpenters would construct the arks to convey the coke by river to market at Cincinnati. Two ovens were built, about 10 feet in diameter. The coal charge was about 80 bushels. In the spring of 1842 enough coke was made to load two boats 90 feet long—about 800 bushels each. These were taken to Cincinnati, but the demand was trifling. Those parties lost heavily in the enterprise and became disgusted with the outlook for marketing coke. This was the beginning of the coke manufacture in the great Connellsville field, which now sends to market annually over 6¼ millions of tons.

The growth of the coke industry was undoubtedly greatly assisted by the excellent product of Connellsville. But the manufacture struggled along up to 1880 without impressing its value as of sufficient importance to give it a place in the statistics of the products of the industries of the United States.

It has now attained a position and magnitude of prime importance in all metallurgical operations.

The following table will show the number of coke establishments in the United States; indicating the growth of the manufacture of coke from 1850 to 1893:

Years.	Number.	Years.	Number.
1850 (census year)	4	1885, December 31	233
1860 " "	21	1886, " "	222
1870 " "	25	1887. " "	270
1880 " "	149	1888, " "	261
1880, December 31	186	1889, " "	252
1881, " "	197	1890, " "	253
1882. " "	215	1891. " "	243
1883, " "	231	1892, " "	261
1884, " "	250	1893. " "	258

NUMBER OF COKE OVENS IN THE UNITED STATES ON DECEMBER 31 OF EACH OF THE YEARS FROM 1880 TO 1893.

States and Territories.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
Alabama	316	416	536	767	976	1,075	1,301	1,555	2,475	3,944	4,805	5,068	5,320	5,548
Colorado	200	267	344	352	409	434	483	532	602	834	916	948	1,128	1,154
Georgia	140	180	220	264	300	300	300	300	290	300	300	300	800	338
Illinois	176	176	304	316	325	320	335	278	221	149	148	25	24	24
Indiana	45	45	37	37	37	37	100	119	103	111	101	84	84	94
Indian Territory	20	20	20	20	20	40	40	80	80	78	78	80	80	80
Kansas	6	15	20	23	23	23	36	39	58	68	68	72	75	75
Kentucky	45	45	45	45	45	33	76	98	132	166	175	303	287	283
Missouri	0	0	0	0	0	0	0	4	4	9	10	10	10	10
Montana	0	0	0	2	5	2	16	27	40	90	140	140	153	153
New Mexico	0	0	0	12	70	70	70	70	70	70	70	*a* 0	50	50
New York	......	......	......	......	......	......	......	......	......	......	......	......	......	12
Ohio	616	641	647	682	732	612	560	585	547	462	443	421	436	435
Pennsylvania	9,501	10,881	12,424	13,610	14,285	14,553	16,314	18,294	20,381	22,143	23,430	25,324	25,366	25,744
Tennessee	656	724	861	992	1,105	1,387	1,485	1,560	1,634	1,639	1,664	1,995	1,941	1,942
Texas	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Utah	20	20	20	20	20	20	20	0	0	34	80	80	83	83
Virginia	0	0	0	200	200	200	350	350	550	550	550	550	594	594
Washington	0	0	0	0	0	2	11	30	30	30	30	80	84	84
West Virginia	631	689	878	962	1,005	978	1,100	2,080	2,792	3,438	4,060	4,621	5,843	7,354
Wisconsin	0	0	0	0	0	0	0	0	50	50	70	120	120	120
Wyoming	0	0	0	0	0	0	0	0	0	0	20	24	24	24
Total	12,372	14,119	16,356	18,304	19,557	20,116	22,597	26,001	30,059	34,165	37,158	40,245	42,002	44,201

a Coke was made in pits.

The above table shows the increase of the number of the coke ovens in each State and Territory from 1880 to 1893.

The ovens are mainly of the Bee-Hive type.

The admirable statistics of the iron trade by Mr. James M. Swank, of Philadelphia, General Manager of the American Iron and Steel Association, show the relative use of the four fuels in the production of pig iron in the United States of America during the five years, from 1887 to 1892, inclusive:

Fuel used—Net Tons.	1887.	1888.	1889.	1890.	1891.	1892.
Coke and Bituminous Coal	4,270,635	4,748,989	5,951,425	7,154,725	6,537,214	7,640,987
Anthracite Coal and Coke	1,919,640	1,648,214	1,575,996	2,169,597	1,747,515	1,756,264
Anthracite Coal alone	418,749	277,515	344,358	279,184	342,526	256,503
Charcoal	578,182	598,789	644,300	703,522	646,200	602,136
Total	7,187,206	7,268,507	8,516,079	10,307,028	9,273,455	10,255,840

The following table shows the production of coke in the several States and Territories from 1880 to 1893:

States and Territories.	1880.	1881.	1882.	1883.	1884.	1885.	1886.
Alabama	60,781	109,033	152,940	217,531	244,009	301,180	375,054
Colorado	25,568	48,587	102,105	133,997	115,719	131,960	142,797
Georgia	38,041	41,376	46,602	67,012	79,268	70,669	82,680
Illinois	12,700	14,800	11,400	13,400	13,095	10,350	8,103
Indiana	0	0	0	0	0	0	6,124
Indian Territory	1,546	1,768	2,025	2,573	1,912	3,584	6,351
Kansas	3,070	5,670	6,080	8,430	7,190	8,050	12,493
Kentucky	4,250	4,370	4,070	5,025	2,223	2,704	4,528
Missouri	0	0	0	0	0	0	0
Montana	0	0	0	0	75	175	0
New Mexico	0	0	1,000	3,905	18,282	17,940	10,236
New York	....	....	....	....	....	....	....
Ohio	100,596	119,469	103,722	87,834	62,709	39,416	34,932
Pennsylvania	2,821,384	3,437,708	3,945,034	4,438,464	3,822,128	3,991,805	5,406,597
Tennessee	130,609	143,853	187,695	203,691	219,723	218,842	368,139
Utah	1,000	0	250	0	0	0	0
Virginia	0	0	0	25,340	63,600	49,139	122,352
Washington	0	0	0	0	400	311	825
West Virginia	138,755	187,126	230,398	257,519	223,472	260,571	264,158
Wisconsin	0	0	0	0	0	0	0
Wyoming	0	0	0	0	0	0	0
Total	3,338,300	4,113,760	4,793,321	5,464,721	4,873,805	5,106,696	6,845,369

States and Territories.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
Alabama.	325,020	508,511	1,030,510	1,072,942	1,282,496	1,501,571	1,168,085
Colorado	170,698	179,682	187,638	245,756	277,074	373,229	362,986
Georgia	79,241	83,721	94,727	102,233	103,057	81,807	90,726
Illinois	9,198	7,410	11,583	5,000	5,200	3,170	2,200
Indiana	17,658	11,966	8,301	6,018	3,798	3,207	5,724
Indian Territory.....	10,060	7,502	6,639	6,639	9,464	3,569	7,135
Kansas	14,950	14,831	13,910	12,311	14,174	9,133	8,565
Kentucky	14,565	23,150	13,021	12,343	33,777	36,123	48,619
Missouri	2,970	2,600	5,275	6,136	6,872	7,299	5,905
Montana	7,200	12,000	14,043	14,427	29,009	34,557	29,945
New Mexico	13,710	8,540	3,460	2,050	2,300	0	5,803
New York	....	....	....	....	....	....	12,850
Ohio	93,004	67,194	75,124	74,633	38,718	51,818	22,436
Pennsylvania	5,832,849	6,545,779	7,659,055	8,560,245	6,954,846	8,327,612	6,229,051
Tennessee	396,979	385,693	359,710	348,728	364,318	354,096	265,777
Utah	0	0	761	8,528	7,949	7,309	16,005
Virginia	166,947	149,199	146,528	165,847	167,516	147,912	125,092
Washington	14,625	0	3,841	5,837	6,000	7,177	6,731
West Virginia........	442,031	531,762	607,880	833,377	1,009,051	1,034,750	1,062.076
Wisconsin	0	500	16,016	24,976	34,387	33,800	14,958
Wyoming	0	0	0	0	2,682	0	2,916
Total............	7,611,705	8,540,030	10,258,022	11,508,021	10,352,688	12,010,829	9,477,580

An inspection of this table indicates that the rank in 1891 of the states which produced over 100,000 tons of coke was as follows: Pennsylvania, Alabama, West Virginia, Tennessee, Colorado, Virginia and Georgia. In all of the years covered by this report Pennsylvania has always ranked first. For most of the years Alabama has occupied a second place, but at times it has dropped as low as the fourth, while West Virginia has assumed the second.

TABLE EXHIBITING THE GROWTH OF THE MANUFACTURE OF COKE IN THE UNITED STATES, 1880 TO 1893, INCLUSIVE.

Years.	Annual Product. — Net Tons.	MILLIONS OF TONS.	Yield of Coal. — Per Cent.
1880	3,338,300		63
1881	4,113,760		63
1882	4,793,321		63
1883	5,464,721		64
1884	4,873,805		61
1885	5,106,696		63
1886	6,845,369		64
1887	7,611,705		64
1888	8,540,030		66
1889	10,258,022		64
1890	11,508,021		64
1891	10,352,688		63
1892	12,010,829		64
1893	9,477,580		63.5

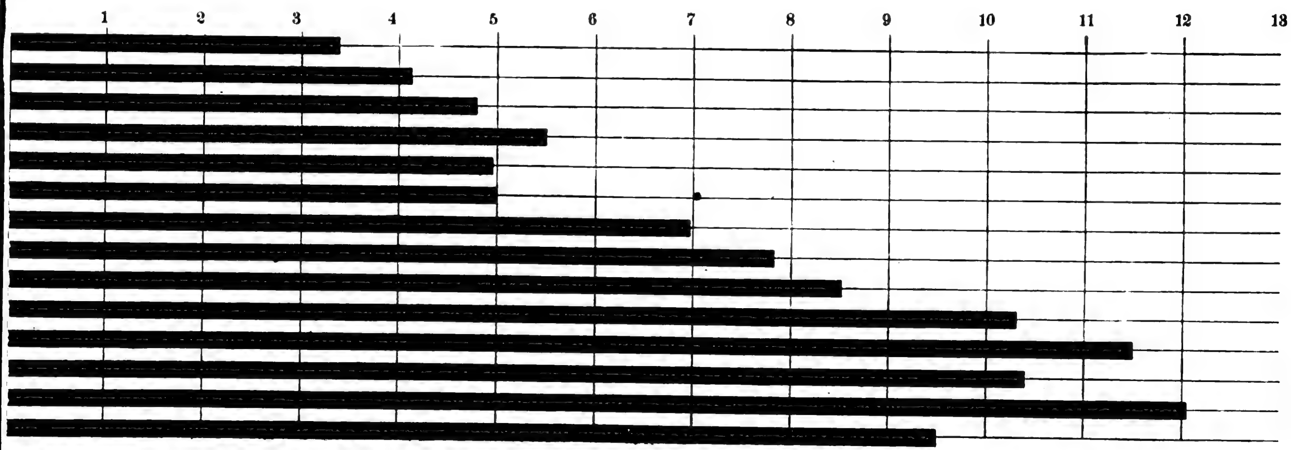
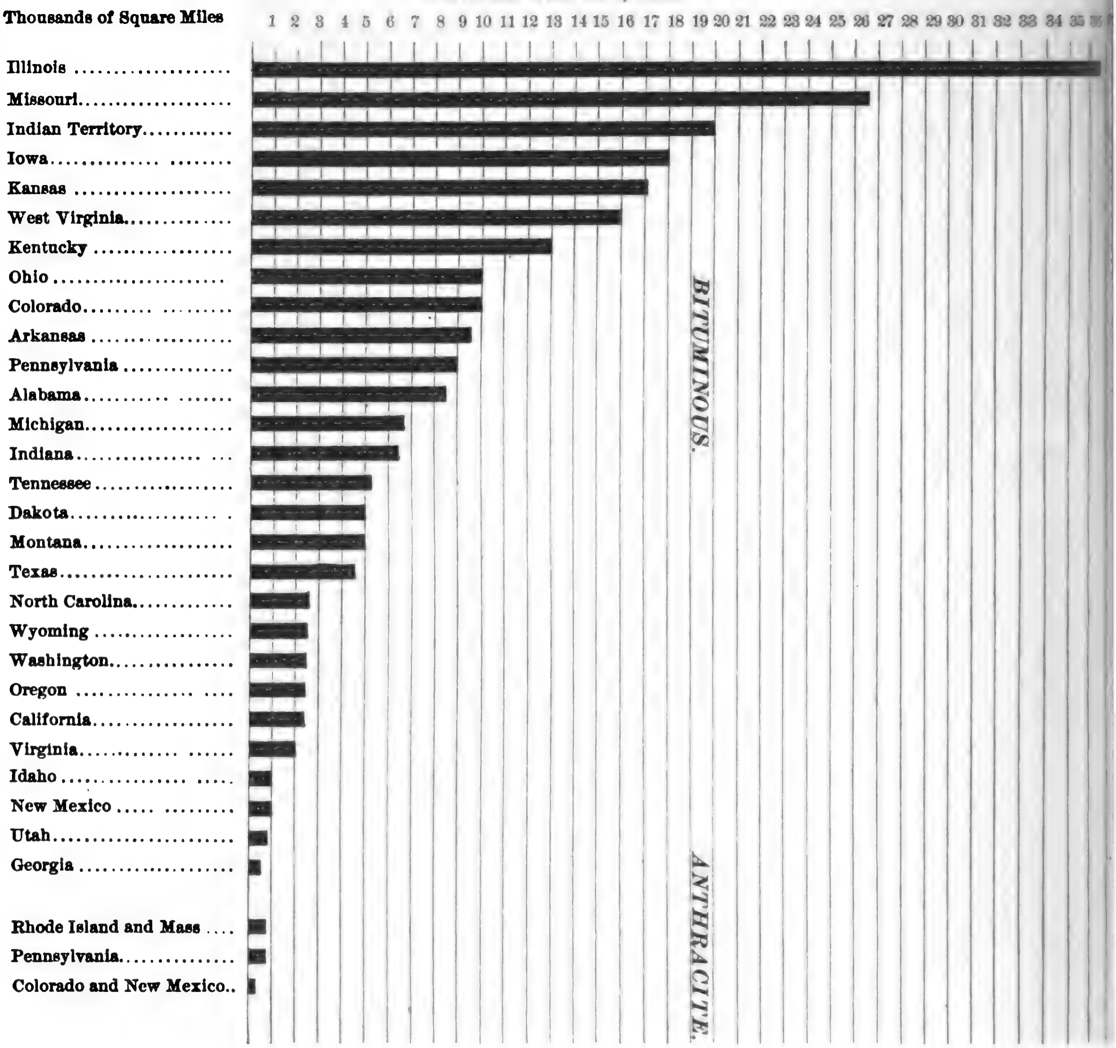


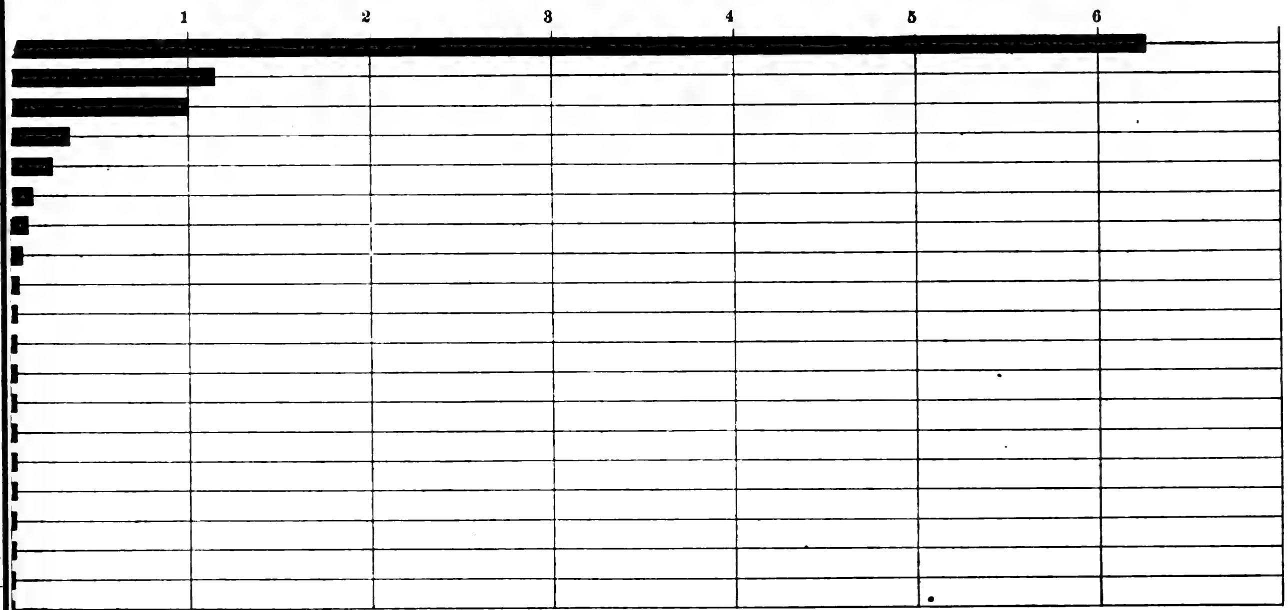
DIAGRAM EXHIBITING THE COAL AREAS OF THE STATES AND TERRITORIES OF THE UNITED STATES, 1893.



MANUFACTURE OF COKE IN THE UNITED STATES DURING THE YEAR 1898.

	NET TONS.
Pennsylvania....	6,229,051
Alabama.........	1,168,085
West Virginia....	1,062,076
Colorado & Utah.	362,986
Tennessee.......	265,777
Virginia.	125,092
Georgia..........	90,726
Kentucky........	48,619
Montana.........	29,945
Ohio	22,436
Wisconsin........	14,958
New York........	12,850
Kansas...........	8,565
Washington......	6,731
Missouri..........	5,905
Indian Territory.	7,135
New Mexico......	5,803
Indiana..........	5,724
Wyoming........	2,916
Illinois...........	2,200
Total...........	9,477,580

MILLIONS—NET TONS.



Value at Ovens, $16,523,714.00.

DIAGRAM SHOWING PRODUCTION OF COAL IN THE STATES AND TERRITORIES OF THE UNITED STATES, 1893.

182,352,774 Net Tons.

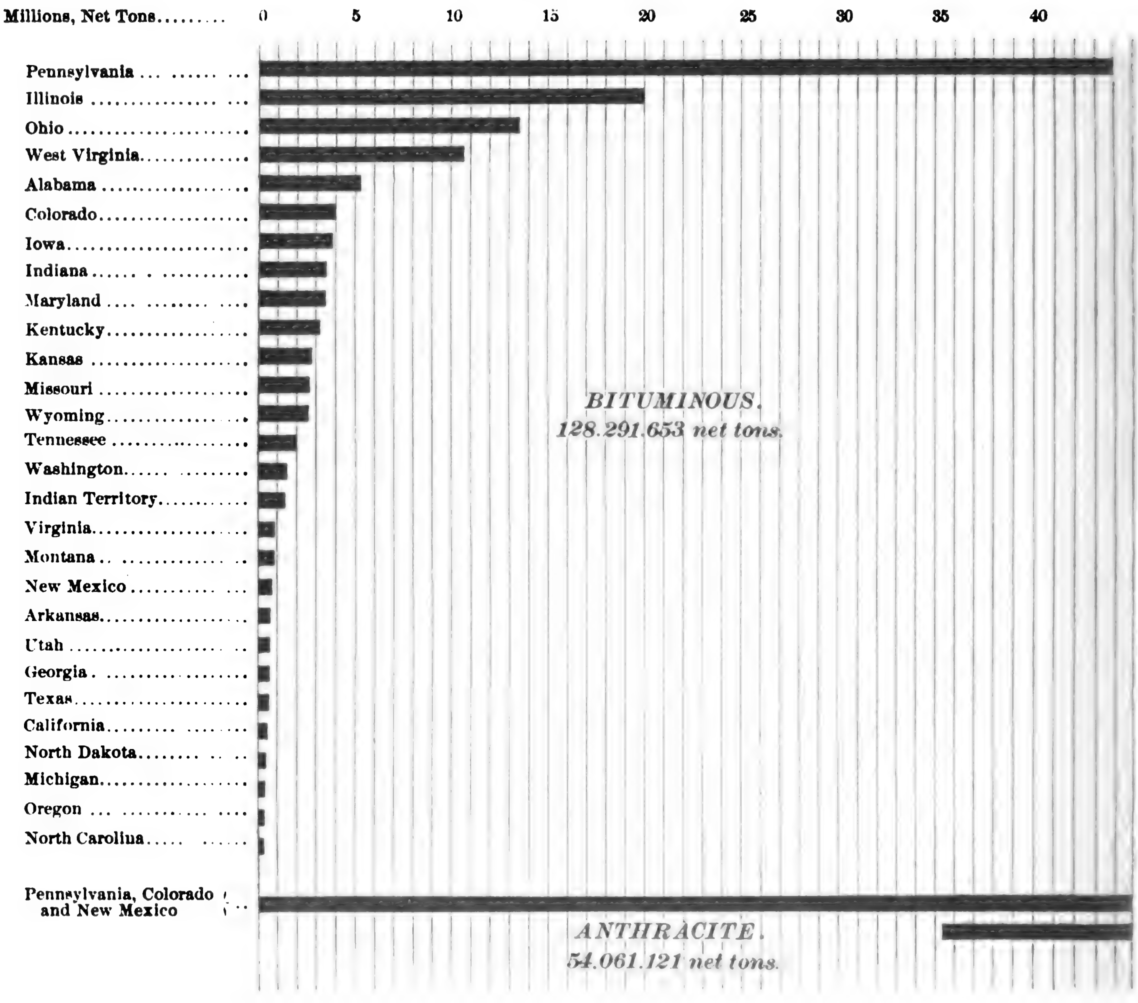
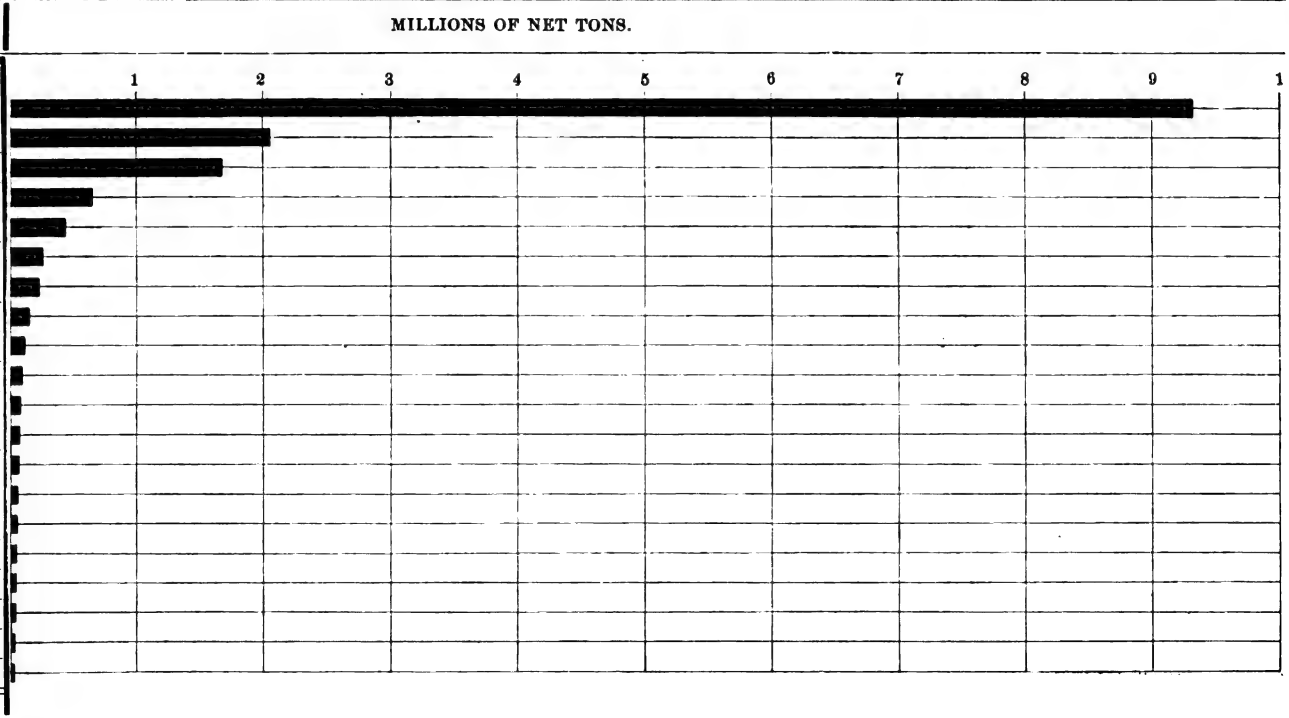


DIAGRAM SHOWING THE AMOUNT OF COAL USED IN THE MANUFACTURE OF COKE IN THE UNITED STATES DURING THE YEAR 1893.

	NET TONS.
Pennsylvania.....	9,386,702
Alabama.........	2,015,398
West Virginia....	1,745,757
Colorado & Utah.	628,935
Tennessee........	449,511
Virginia	194,059
Georgia..........	171,645
Kentucky........	97,212
Montana	66,770
Ohio.............	42,963
Wisconsin,impt'd	24,085
Indian Territory.	15,188
New York,impt'd	15,150
New Mexico......	14,698
Kansas..........	13,645
Indiana.........	11,549
Washington... ..	11,374
Missouri	8,875
Wyoming	5,400
Illinois..........	3,300
Total..........	14,917,146



The following table from Mr. J. M. Swank's "Iron in all Ages," will exhibit in a very interesting way the struggle of these fuels for supremacy, with their present ranks, *the coke leading all others:*

Years.	Charcoal.	Anthracite.	Coke.	Remarks.
1854........................	342,298	339,435	54,485	All net tons.
1855........................	339,922	381,866	62,390	Anthracite leads Charcoal.
1869........................	392,150	971,150	553,341	Coke leads Charcoal.
1875........................	410,990	908,046	947,545	Coke leads Anthracite.
1890........................	703,522	2,448,781	7,154,725	Era of Coke.

This exhibit establishes the fact, that the use of *coke* in smelting iron is largely on the *increase*, and that the use of anthracite coal is *decreasing*, especially when used alone in blast furnaces; whilst charcoal in its limited use, appears to be nearly stationary.

As coke is now the *chief fuel* in the metallurgy of iron and steel, and its use is steadily increasing, it is evident that it is destined to maintain its prominent place of usefulness in the coming ages; increasing in largest proportion with the expansion of the manufacture of iron and steel.

The table also shows that coke is superseding anthracite coal in blast furnace operations.

Where the relative cost of coke to anthracite coal does not largely exceed 25 to 30 per cent., the former fuel would probably obtain the preference, from its greater calorific energy in the production of a larger output of pig-iron in the furnace.

At present, furnaces within the borders of the economic bounds of coke, are using this fuel mainly and obtaining supplies from the Connellsville, Alleghany, and Clearfield regions.

Mixtures of coke with anthracite coal are made at some furnaces, ranging from ⅛ to ½ of the fuel charge. It is evident, however, that the use of coke in blast furnaces is steadily on the increase and will continue to enlarge the bounds of its usefulness, displacing the less energetic anthracite fuel.

From the limited area of the chief anthracite coal fields in the east, containing in the aggregate only 488 square miles of coal measures; and from its present large annual output of 53,967,543 net tons in 1893; with a deeper and increasing cost of mining; it cannot long profitably continue to supply furnace fuel at very low rates.

The charcoal fuel for blast furnace use, under the rapid cutting down of the primeval forests, must continue to afford only a limited supply and its use be confined to the smelting of pig metal for special purposes.

From all the foregoing it will be seen that the present and future manufacture of coke demands and should receive increased and earnest attention.

This is further impressed, not only from its prime value as a metallurgical fuel, but also from the very great source of the supply of coal for its manufacture, covering an area in the United States of North America, of about 250,000 square miles.

It is evident, however, that only a small area of these coal fields afford the *best* coal for coke making such as the Connellsville, Punxsutawney, Allegheny and Broad Top in Pennsylvania; Pocahontas in Virginia, and the new regions of coking coals in West Virginia.

Alabama also affords a very good coal for coke making. In Kentucky, at Pineville and Big Stone Gap, excellent coking coals are found in abundance.

At El Moro, in Colorado, very good coke is made from a large bed of coking coal.

But with all these and many others, yet to be developed, the aggregate ratio of the *best coking coals* to the whole coal area, is *very small.*

As long as the supply of coke can be maintained from these good coking coals, the methods of coking do not urge or compel extended consideration; but when the less valuable coals for coking purposes come into use, the studies of the preparation of the coal for coking, with the kind of coke oven best adapted for each quality of coal, will become of vital importance.

When the time approaches for these investigations to be taken up by coke makers, it will be found that three principal conditions will require careful study: 1st. The preparation of coal for coking; 2d. The kind of coke oven best adapted for securing the best quality of coke from each variety of coal; and 3d. The saving of the by-products in coking, consisting of sulphate of ammonia and tar. This will also require arrangements in coke ovens, as well as the outside conduits, condensers, etc., etc.

The rather poor quality of coking coals on the continent of Europe, has long ago compelled thorough attention to the preparation of these coals for coking, as well as to the development of the oven best suited to their wants in making from them the best possible coke, and, during the past decade, to the saving of the by-products in coking.

The American coke manufacturer has before him a much easier task than the Belgium, German, or French coke makers; from the larger supply of coking coal requiring no special treatment in producing the best qualities of coke. Even when the exhaustion of these good coals approaches, the second quality will be found to be superior to the continental coals.

From this large and increasing use of coke, it is evident, that its manufacture will demand the earnest and diligent efforts of those in charge of the several processes in its preparation and coking.

Nor is this industry any exception to the general law governing all industries; small beginnings, protracted and anxious struggles for success, with the reward crowning all persistent and well directed efforts.

There is, therefore, a deep interest attached to the study of the several steps in the upward progress in the manufacture of coke, especially in its early stages and up to its present advanced progress in the industrial arts.

In this chapter it is designed to consider the conditions in the treatment of coal in the early methods in coking, from the open air pits or mounds to the advent and progress of the closed retort coke ovens of the present time.

COKING COAL.

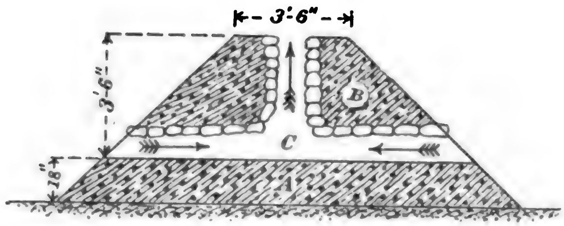
Coking is the art of preparing, from bituminous coal, fuel adapted for metallurgical and other special uses.

The operation consists in expelling, by heat, the gaseous elements from coking coals, leaving the fixed and deposited carbon, ash and the residue of sulphur and phosphorus which constitute the *coke.*

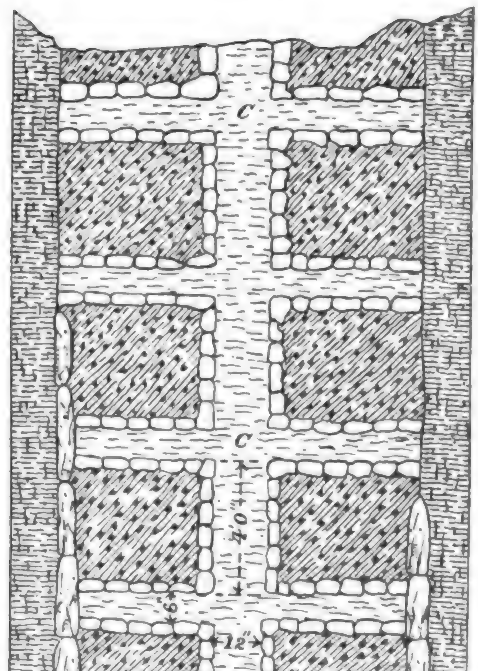
FIRST—COKING COAL IN HEAPS OR MOUNDS.

The open air coking in heaps or mounds has been copied after the charcoal burners.

This primitive and wasteful mode of coking coal requires a yard made by levelling the ground and surfacing it with coal-dust. The coal to be coked is then arranged in rectangular heaps or mounds, with longitudinal transverse and vertical flues; sufficient wood having been distributed in these to ignite the mass of coal. See Fig. 31.



Cross Section.



Ground Plan.

FIG. 31.—BENNINGTON COKE PITS.

Beginning on this prepared floor, a base of coal 14 feet broad is spread to a height of 18 inches, *A*. On this base the flues are arranged and constructed as shown in the plan—the coal is piled up as shown in the upper section *B*.

The flues are built of refuse coke and lump coal, and covered with suitable billets of wood. When the mound is ready for coking, fire is applied at the base of the vertical flues *C*,*C*, igniting the kindling wood at each alternate flue.

As the process advances, the fire is extended in every direction, until the whole mass is ignited.

Considerable attention is required in this method of coking, in constructing the mounds, in diffusing the fire evenly through the mass, in preventing waste by admitting the proper volume of air, and in banking up the mounds with fine dust as the coking operation is completed from base to top.

When the gaseous matters have been expelled, which is seen when flames cease to appear, then the whole heap is closed up with fine dust, and partially smothered out in this way.

The final operation consists in the application of small quantities of water, delivered by a hose down the flues, which is quickly converted into steam premeating the whole mass of coke. This gives coke with freedom to develop cells and with a small percentage of moisture under careful management.

The time required for coking a mound of the dimensions given, without limiting its length, is from five to eight days, depending on the state of the weather.

The yield of coke, at the Bennington Yard, is as follows:

Coal used in mound	56.87 gross tons.
Coke drawn-mound	33.63 gross tons.
Loss in coking	23.24 gross tons.

From this it will be seen that the yield of coke is 59.13 per cent.; and the loss 40.87 per cent.; 1.69 tons of coal to 1 ton of coke.

The composition of the Miller Seam coal (B), used for making coke in these mounds, is as follows:

Volatile matter	22.38 per cent.
Fixed carbon	68.50 per cent.
Ash	8.00 per cent.
Sulphur	1.12 per cent.
	100.

As the fixed carbon, ash and 60 per cent. of the sulphur make coke, which in this case amount to 77.17 per cent., and as the yield of coke was only 59.13 per cent., the loss of fixed carbon was at least 26.34 per cent. of the amount originally in the coal.

It appears from this large loss of carbon in coking, that very little has been deposited from the volatile hydro-carbon in the coal.

The progress of coking from flue *C*, near the base of the coal heap, upwards, fails to secure any of this addition to the fixed carbon in the coal.

Coal has also been coked in dome-shaped mounds, in the early efforts in coking, but this method and its results, do not vary much from the foregoing.

Some efforts at progress, in methods of coking, appear to have made in this period of evolution, by a plan for coking in open top rectangular inclosures. These were made with built side walls, 5 to 8 feet in height, along which air ports were made.

The methods of coking in this walled kiln are very similar to those used in the mound coking; it has nothing to commend it in economy of work, saving of carbon or quality of coke over the mound methods. Its coke was evidently made under pressure, as the charge of coal was "packed" in the walls, and a *dense* coke must have resulted.

All that can be said in its favor is, that it was a step in the progress of improvement to the modern coke oven.

THE BEE-HIVE COKE OVEN.

The initial form of the Bee-Hive coke oven is given in the following drawing, Fig. 32, which shows the effort to introduce a partially inclosed oven early in the manufacture of coke.

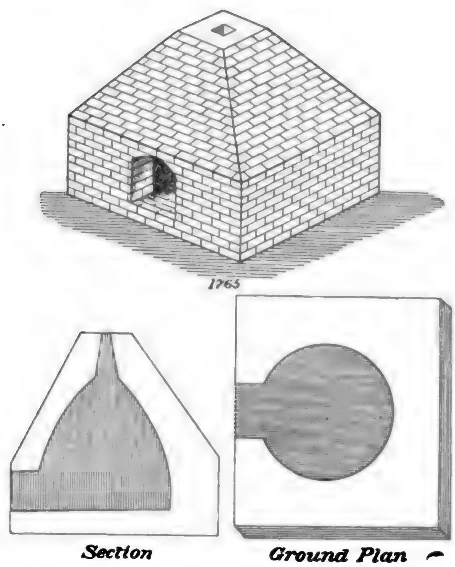


FIG. 32.—PLAN OF COKE OVENS NEAR NEWCASTLE-UPON-TYNE.*

It is not very clear whether this plan of oven was suggested by the form of the dome shaped mound method of coking coal or from the charcoal kilns, evidently the latter dominated the Bee-Hive plan.

The name "*Bee-Hive*" evidently had its genesis in the close resemblance of the internal form of this oven to the ancient dome shaped "*Bee-Hive.*"

It was built with refractory materials and in some instances had flues in its heavy walls.

The product of this oven could not differ much from that of the modern Bee-Hive oven of 1880–1890, only the waste of carbon in the former was much more than in the improved oven.

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* From Mr. A. L. Steavenson, in Vol. VIII., North of England Mining Engineers, 1860.

The "*ancient*" Bee-Hive coke oven was evidently constructed on a diminutive scale, in the day of small things, but it has held its place and grown in size through a century and a quarter, until it has attained dimensions of 12 feet to 12½ feet in diameter, with height of dome above floor, of 6 feet to 7 feet.

The height of the door of this oven has been increased so as to admit the air at a level somewhat above the charge of coking coal to prevent the waste formerly sustained at this place, by contact of the air with the coke in low-door ovens, leaving a deposit of ashes along the line of this air draught.

A number of improvements have been made in the construction of this oven, especially in the preparation of shaped fire brick for doors, jambs, dome and charging port.

In some ovens an annular passage for the admission of air, with perforations for its equal distribution, above the level of the charge of coal, has been tried with increased economy in saving the burning of the carbon of the coal.

SPECIFICATIONS FOR CONSTRUCTING THE MODERN BEE-HIVE COKE OVEN.

Excavations for Foundations.—The excavations of all foundations for mason work should be cut to such depth, beneath the surface of the ground, as will insure stability to the masonry and exemption from disturbance from frost.

Masonry of Retaining Walls.—The masonry of the retaining walls of the Bee-Hive coke oven should be built of sound sandstones, of even beds and of such thickness as hereafter described.

The first two feet of the foundation of these retaining walls should be laid dry with large flat stones, carefully bedded so as to secure a permanent foundation.

Above this foundation course, the masonry should be laid in lime mortar, composed of two parts of clean sharp sand and one part of good slacked lime, thoroughly mixed so as to insure thorough blending of materials.

The stone should be sufficiently large and well shaped for this purpose to make good bond and strong work. The outer face of this masonry should be neatly trimmed and the bedding of the stones dressed so as to lie firmly upon each other, without the aid of chip and pinners. The thickness of the stones, up to the level of the bottom of the coke ovens, should not exceed twelve inches.

The face of the wall should be carried up with a uniform batter of two inches per vertical foot, from the level of the top of the two feet dry foundation masonry, to top of oven bank.

Seats for the base of iron door frame of coke oven should be carefully dressed to an even surface, in harmony with the plan for same.

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Filling to Oven Base.—The filling under the oven seats should be begun at surface of ground. The surface of ground should be cleared of all vegetable matter.

The filling should be made of earth or loam, which must be selected for this purpose, and all vegetable or other unsuitable matters removed.

The filling should be made in horizontal layers, not exceeding one foot in thickness. It should be thoroughly watered and packed in a solid manner by rammers or rollers, so as to insure a permanent foundation for the ovens without shrinking or settling.

To assure permanency in this filling, a sufficient time should be allowed it for settling and drying, from three weeks to one month.

Building Coke Ovens.—The Bee-Hive coke oven should be built in accordance with the plans shown in Fig. 33. They should be built of shaped fire brick with a composition of materials especially suited for the service demanded in their use—strong heats with water contact in quenching the coke inside the oven.

This requires a coarse physical composition in the fire brick.

The circular coke oven foundation should rest and be founded upon a repacked zone or ring base, twelve inches wide, and conforming to the inside diameter of oven of twelve feet.

The first section of the oven should be circular, 12 feet in diameter, in the inside of the oven, and built with fire-brick shaped to conform to the radial lines of the circular portion of oven.

The line of this inner circle of oven should be defined by a sweep, pivoted on the center of this section of oven.

The dome of oven should be built with its appropriate brick guided by a sweep, or on centers, as the superintendent or engineer in charge may direct.

The whole should be carefully and firmly keyed by the circular charging port ring on crown of oven.

The oven door jambs, with arch brick connections, should be neatly and carefully laid so as to make strong work and thorough bond. The arch on the cast-iron oven door frame should be omitted. The setting of this frame, supplementing the jamb brick, should be made of well burned red brick, as shown on the drawings.

The mortar used in the fire-brick work of the ovens should be composed of loam, or loam and clay, in such proportions as the superintendent or engineer may direct. The materials should be thoroughly blended and mixed with water to such consistency as may be approved.

The tiles on bottom of oven to be laid on a bed of sand three inches thick and firmly bedded in it.

The retaining walls from the level of bottom of ovens to the top of ovens, should be built of sound sandstone laid in lime mortar of the composition before described, with the batter of two inches per vertical foot

continued to the top. The stones should be carefully selected for this use, the thickness should not exceed the maximum thickness of 6 inches, or be less than 3 inches.

Great care should be required in the bedding and bond of the stones in constructing this section of the retaining walls of the coke ovens.

The filling between the coke ovens should be composed of clay or loam, to be carefully compacted with rammers in layers of one foot deep, with special care in ramming the filling in contact with the brick masonry of the ovens.

Especial care should be taken in selecting material, for filling around the ovens, that is not fusible at low heats.

Coke Oven Wharves.—The coke wharves should be at least 36 feet broad, with the surface 2 feet 9 inches to 3 feet below the level of the bottoms of coke ovens.

The retaining cribbing or stone wall should be constructed in such a manner, so as to maintain the filling materials of the wharves in a firm condition.

The height of the wharves above the level of the railroad sidings should be from 7 to 12 feet. This elevation to be regulated to meet the heights of coke cars used in this service.

The filling of the coke oven wharves should be made of clay, loam or rocks as may be found most convenient.

The grade of the bank of coke ovens should be one foot fall in each one hundred feet long, so as to equalize the work of charging the ovens with the larry and to enable rail cars on the sidings to be moved without the use of a locomotive.

The plumbing and water supply should receive attention in affording ample section of pipes for the conveyance of water and the quality of the water used in cooling coke.

Measurements.—All the stone masonry necessary to the completion of the coke oven, should be measured in the wall with dimensions as given on plan. All masonry should be estimated and paid for by the cubic yard of twenty-seven cubic feet.

These measurements should be the actual cubical contents of such walls, without any of the city allowances for vacant places, corners, etc., etc.

The masonry of the ovens completed should be paid for by the oven, without reference to the cubical contents.

The filling under and around the coke ovens and in wharves, should be measured and paid for by the cubic yard of twenty-seven cubic feet.

The measurements should be the actual cubical contents without any allowances.

The foregoing plans, sections, with details and specifications for construction, will afford full information in regard to the construction of the modern average sized Bee-Hive coke oven.

An additional plan and section is given, Fig. 34, illustrating the larger Bee-Hive coke ovens recently constructed at the Oliver plant, near Uniontown, in the Connellsville region.

These have been kindly furnished by Messrs. Wilkins and Davison, Engineers, Pittsburg, Pa., who are experts in this and kindred constructions.

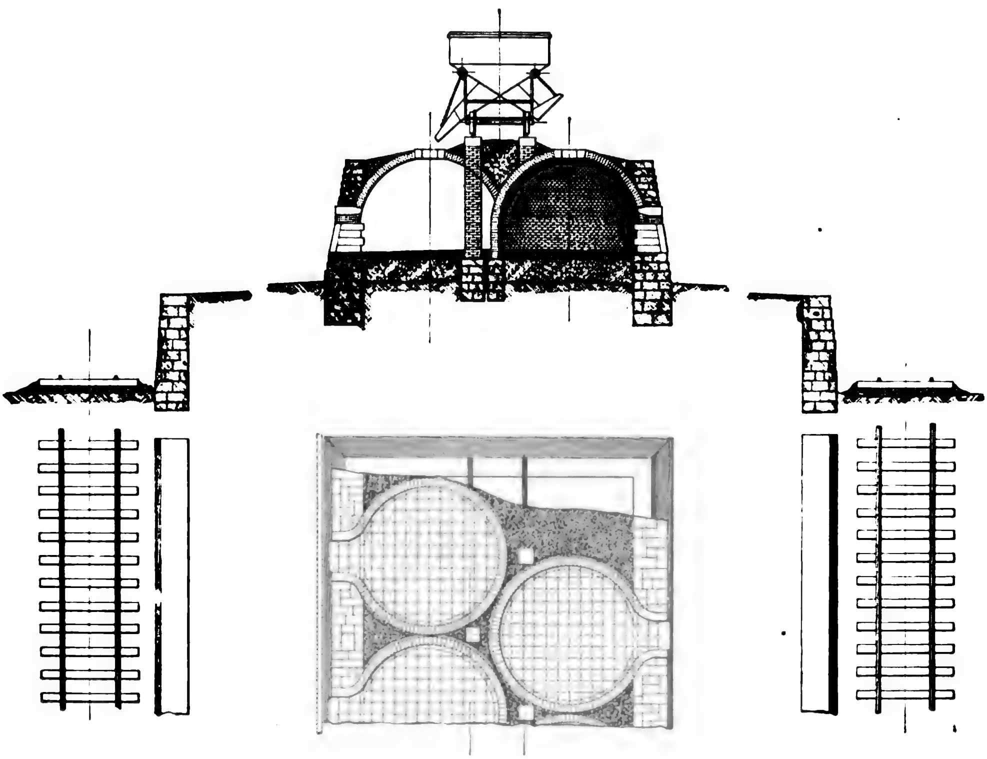


FIG. 34.—PLAN AND SECTION OF BEE-HIVE OVENS.
BY WILKINS AND DAVISON, ENGINEERS, PITTSBURG, PA.

With a few unimportant exceptions. the 44,201 coke ovens in the United States, at the close of the year 1893, were after the Bee-Hive plan.

The chief and sustaining value of the Bee-Hive coke oven consists in its production of the *best quality of metallurgical fuel* from the prime coking coals.

In order to secure this result, the use of the best coking coal is an imperative requirement.

This result is assured by the freedom of the coal in the process of coking, affording the best possible physical structure in the product of coke.

An additional advantage is secured in the closing operation by watering or cooling the coke in the oven, reducing the moisture in the coke to the least possible quantity.

The operations of this oven secure the two most desirable properties of coke, in its full cellular developments, assuring maximum calorific energy and the dry condition of the coke with minimum percentage of moisture.

It may be conceded, however, that the cost of labor and waste of carbon in coking in the Bee-Hive oven are somewhat in excess of similar work in some of the modern vertical coke ovens.

In the further consideration of the work of the modern Bee-Hive coke oven, and for the purpose of determining its exact percentage of coke product, an exhaustive series of experiments have been made at the large coking plants of the Cambia Iron Company in the Connellsville region under care of Mr. Isaac Taylor.

The following cross-section of 48 and 72 hours charges of coal in these ovens, Figs. 35 and 36, will show the process of coking from top of charge to floor of oven, with the enlargement and shrinkage of the resultant coke carefully and accurately defined from the actual work of these ovens.

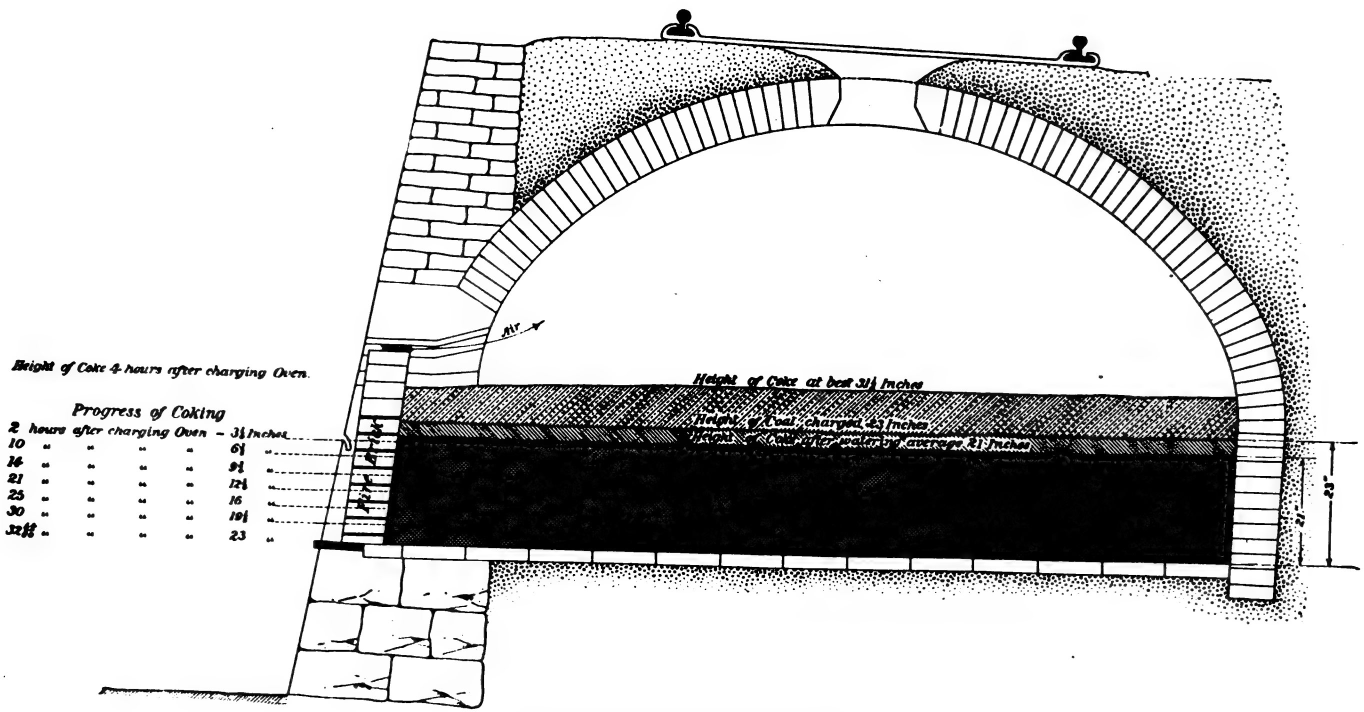


Fig. 35.—48 HOURS COKE CHARGE.

TABLE A.—TEST EXPERIMENTS IN COKING.

CONNELLSVILLE REGION. DEC. 1892.

No. of Test.	When Charged.			When Drawn.			Time in Oven.		Coal Charged.	Ash Made.	Fine Coke Made.	Market Coke Made.	Total Coke Made.	Per Cent. of Yield.				Per Cent. Lost.	Remarks.
	Month.	Day.	Hour.	Month.	Day.	Hour.	H.	M.	LBS.	LBS.	LBS.	LBS.	LBS.	Ash.	Fine Coke.	Market Coke	Total Coke		
1	Dec.	14	11.00 A. M.	Dec.	16	7.00 A. M.	44	00	10,400	84	209	6,922	7,131	00.81	2.01	66.56	68.57	30.62	Watered in Oven.
2	Dec.	16	10.00 A. M.	Dec.	19	8.00 A. M.	70	00	12,400	103	264	8,060	8,324	00.83	2.13	65.00	67.13	32.04	Watered in Oven.
3	Dec.	17	9.00 A. M.	Dec.	20	7.00 A. M.	70	00	11,430	94	282	7,640	7,922	00.82	2.47	66.84	69.31	29.67	Watered in Oven.
4	Dec.	19	11.00 A. M.	Dec.	21	7.00 A. M.	44	00	9,420	75	249	6,260	6,509	00.80	2.64	66.45	69.09	30.11	Watered in Oven.
Totals and Averages.									43,650	356	1,004	28,882	29,886	00.82	2.30	66.17	68.47	30.71	

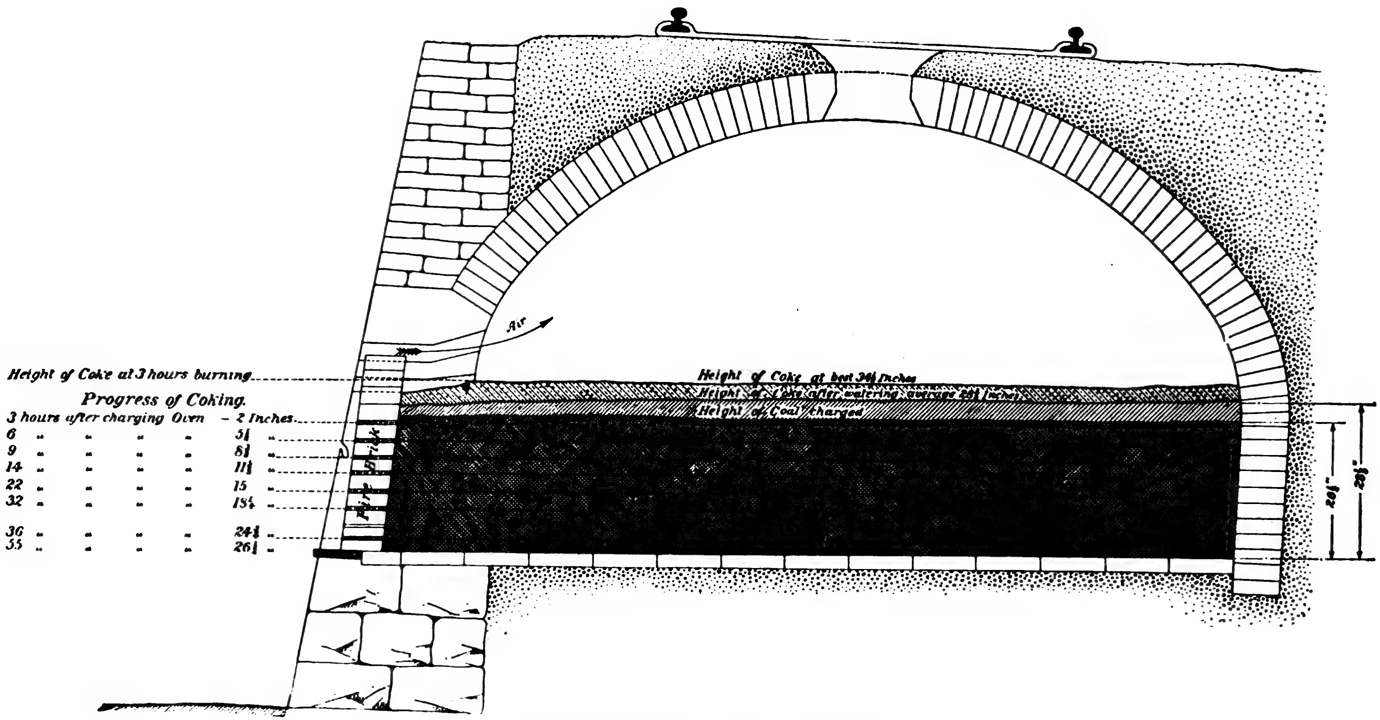


FIG 36.—72 HOURS COKE CHARGE.

TABLE B.—TEST EXPERIMENTS IN COKING.

CONNELLSVILLE REGION. DEC. 1892.

No of Test.	When Charged.			When Drawn.			Time in Oven.	Coal Charged.	Ash Made.	Fine Coke Made.	Market Coke Made.	Total Coke Made.	Per Cent. of Yield.				Per Cent. Lost.	Remarks.
	Month.	Day.	Hour.	Month.	Day.	Hour.	H. M.	LBS.	LBS.	LBS.	LBS.	LBS.	Ash.	Fine Coke.	Market Coke.	Total Coke.		
1	Dec.	16	12.00 M.	Dec.	19	7.00 A. M.	67 00	12,420	99	385	7,518	7,903	00.80	3.10	60.53	63.63	35.57	Hot or Dry Tests
2	Dec.	17	11.00 A. M.	Dec.	20	7.00 A. M.	68 00	11,090	90	359	6,580	6,939	00.81	3.24	59.33	62.57	36.62	Hot or Dry Tests
3	Dec.	19	10.00 A. M.	Dec.	21	7.00 A. M.	45 00	9,120	77	272	5,418	5,690	00.84	2.98	59.41	62.39	36.77	Hot or Dry Tests
4	Dec.	20	10.00 A. M.	Dec.	22	7.00 A. M.	45 00	9,020	74	349	5,334	5,683	00.82	3.87	59.13	63.00	36.18	Hot or Dry Tests
Totals and Averages.								41,650	340	1,365	24,850	26,215	00.82	3.28	59.66	62.94	36.24	

From these sections and the accompanying tables it will be readily seen that the average charge of coal for 48 hours coke is 9,910 pounds, or 5 net tons nearly. It occupies a depth in the coke oven of 23 inches.

The charge of coal for 72 hours coke is 11,915 pounds, or 6 net tons nearly. It has a depth in the oven of 26½ inches.

The process of fusing and coking begins on the top surface of the charge of coal, and goes down through the mass of coal at the rates shown in the margins of the sections, until it reaches the bottoms of the ovens.

It will also be seen that in this process of coking, hydro-carbon gas will be evolved from the coal, which, passing up through the fissures of the incandescent section of coked coal, deposits some of its carbon.

This gives the coke the bright silvery coating which distinguishes the best cokes and partly protects them from dissolution, in the upper region of blast furnaces, from the action of the ascending gases.

These sections show, in a graphic way, the heights of 48 and 72 hours coke in the ovens at "best," and its reduced altitude after being cooled by watering in the oven.

The following tables of careful tests show in accurate details two series of determinations to learn the exact percentage of coke produced, under careful management in the Bee-Hive coke oven:

They give the average results, from an equal number of tests of 48 and 72 hours charges of coal in the product of coke.

One table shows the percentage of coke obtained in the usual practical method of cooling the coke by watering in the oven; the other table shows the percentage of hot coke without having been watered in the oven.

Table A exhibits the usual and practical percentage of coke made in these ovens in the usual way with the moisture from cooling in the oven included.

Table B shows the exact percentage of coke as it has been drawn in a red hot condition and exempt, or nearly so, from moisture.

This latter determination is impracticable, but it was made to ascertain the ratio of carbon waste by the Bee-Hive oven method of coking.

In all these experimental tests the coal charged into ovens and the products in marketable coke, fine coke or breeze and ashes have been carefully separated and accurately weighed.

In the preparation for these tests, two samplings of the coal, from the large 8 ft. Connellsville bed, were taken and analyses made in the Cambria Iron Company's laboratory at Johnstown, by Dr. James J. Fronheiser, chief chemist, affording the following results:

Moisture 212° F	1.25
Volatile matter	31.80
Fixed Carbon	59.79
Ash	7.16
Sulphur	0.53
Phosphorus	0.024

From the above it will be evident that the maximum of coke, assuming that about 40 per cent. of the sulphur in the coal is volatilized in coking, will be as follows:

Fixed Carbon	59.79
Ash	7.16
Sulphur	.32
Total Theoretic Coke	67.27

In coking, some of the fixed carbon of the coal is consumed, and on the other side some carbon has been deposited from hydro-carbon gases evolved from the coal in the process of coking.

In table A, the total percentage of coke, made from the coal charged, and watered in the oven, in the usual and practical way, is 68.47 per cent.; exhibiting an increase over the theoretical percentage of coke of 1.75 per cent.

Then the 62.94 per cent. of dry coke falls under the theoretic 67.27 per cent. of coke; exhibiting a loss or waste of fixed carbon in coking of 6.45 per cent. Taking the percentage of *dry coke* at 62.94, it will require 1.59 net tons of coal to make 1 net ton of coke.

Or, in whole numbers, in making 63 per cent. coke, 1.6 tons of coal will be required in charging the ovens to produce 1 ton of coke.

Practically, table A shows that Connellsville coal, coked in the modern Bee-Hive oven, will produce under careful and intelligent management 66.17 per cent. of marketable coke, 2.30 per cent. of small coke or breeze and 0.82 per cent. of ashes.

The average gaseous products expelled from the coal in coking is 30.71 per cent.

This enlarged product of coke (66.17 per cent.) has been obtained by improved methods in coking, by reducing the waste of fixed carbon at doors of ovens by increasing their height so as to admit air above the charge of coal in the oven, thus avoiding the old-time wastage at this place.

There is also a deposit of carbon from the expelled volatile hydrocarbons of the coal in coking in their upward passage through the incandescent coke, especially noticeable in the upper section of coke.

Just how much carbon is deposited under the varying conditions in coking 48 and 72 hours coke, has not yet been accurately determined.

After some experiments, in a crucible, in coking Connellsville coal, it was found that, under conditions similar to those of the Bee-Hive oven, and admitting proportional volume of air, the resultant dry coke was 67.56 per cent., which is slightly in excess of the theoretic or calculated yield of coke from this coal—67.27 per cent.

A second experiment consisted in the exclusion of air; using the true retort method in coking. This gave 79.20 per cent. of coke.

We have, therefore, the two results:

First.—By admitting air—67.56%.

Second.—By excluding air—79.20%.

Exhibiting an increase by the latter method of 11.64 per cent.

As the first coking test gives full theoretic result of coke, it is evident that there was no burning or waste of fixed carbon, or if any was wasted an equal amount of deposited carbon must have replaced it.

In the second test, there was evidently a large deposit of carbon from the gases of the coal, at least 14.71 per cent., assuming that no fixed carbon has been burned in this retort test.

Practically, no construction of coke oven could afford the precision of admitting air and absolutely excluding it, as in these laboratory tests.

They show, however, that the retort oven methods of coking affords a larger yield of coke than can be obtained by the Bee-Hive or air oven methods of coking.

The relative calorific values of the coke made in these two principal methods will be taken up in a subsequent chapter.

OLD WELSH OVEN.

In the progress of the manufacture of coke, the elements of cost appear to have invited attention to the laborious and expensive methods of drawing coke from the old and cramped Bee-Hive ovens.

The main effort in reducing cost was directed to a new plan of coke oven, retaining the principles of the Bee-Hive but planning the new oven, so as to draw the coke by mechanical appliances.

The Welsh oven consisted of an arched chamber 12 feet long, 7 feet broad, and about 6 feet high.

One end of this oven is walled up, the other end or front has doors or luted walls. A flue chimney at the closed end of the oven affords egress to the gases.

The coke is drawn out by a "drag." This drag is composed of a main iron bar running the length of the oven and having a cross piece at the inner end. The whole drag is placed in bottom of oven before the charge of coal is placed in it.

It remains under this charge of coal until it is coked and ready for drawing out, when a chain is attached to an eye in the drag at front of oven, pulling out the coke, in mass, by windlass or engine power.

The coke is usually quenched or cooled outside the oven.

With skill this method of coke manufacture possesses some advantages in the economy of the work in drawing the coke out of oven, without injuriously affecting the physical condition of the coke.

The cooling outside the oven, by watering, is the chief objectionable feature in this section of the work of coking, as coke watered in this way, if done in a clumsy manner, would contain from eight to fifteen per cent.

of water, neutralizing the advantage secured in the rapid drawing of the coke by mechanical means.

This effort at the improvement in the coke oven to save labor, has been followed by other plans on the same general principles, but mainly designed at improvement in the details of these methods of the several operations in coking.

THE THOMAS OVEN.

The Thomas oven is simply an improved "Welsh oven;" preserving the desirable properties of the Bee-Hive oven in coking the coal. It secures some economy over the latter by its mechanical method of drawing its coke. It retains, however, the undesirable method of cooling the coke by watering it outside the oven.

This oven has been fully described in a paper prepared by Mr. J. T. Hill, manager of the Coalburg mine, and read at the meeting of "The Alabama Industrial and Scientific Society" in 1891.

The accompanying drawing (Figs. 37, 38 and 39), illustrate its main features.

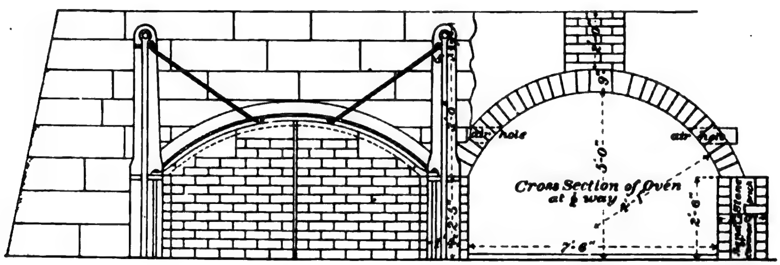
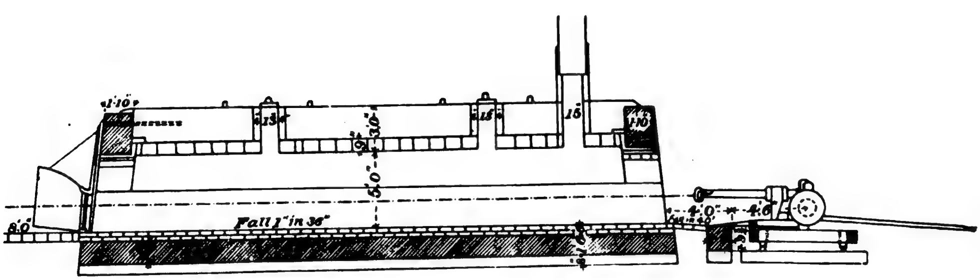


FIG. 37.—THOMAS OVEN.



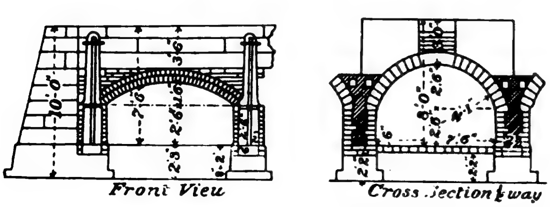


FIG. 38.—THOMAS OVEN

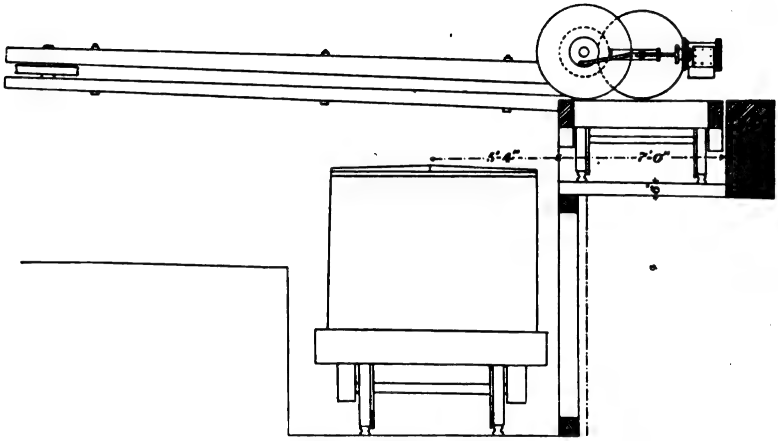


FIG. 39.—THOMAS OVEN.

The descriptive text is as follows: "The essential difference between the 'Old Welsh oven' and the 'Thomas' exists in the facts, that the latter is much longer, affording greater capacity, and that both ends are movable; thus doing away with the necessity of placing the drag in the oven prior to charging. In nearly every respect the ovens are identical.

"At Coalburg there are 64 Thomas ovens arranged in one single continuous battery.

"In construction, the same principles are carried out and materials used as in the Bee-Hive ovens, except that the bottoms are of hard red brick, upon the theory that they resist the wear of the drag better than the fire brick. In detail they are described as follows:

Length	36 feet.
Width inside	7 feet 3 inches at back.
Width inside	7 feet 9 inches at front.
Height over all	8 feet.
Height of door	4 feet.
Height inside	5 feet to crown of arch.

"Fall in bottom from back door to front, 1 inch in 3 feet, or 1 foot in the whole length of oven.

"Both *back* and *front* are movable and have swinging doors, which are in two sections, and built of fire brick of special design, laid in iron frames.

"There are three openings on top—two funnel heads and one draft stack near the back end of the oven.

"In front of it, and on a level with the floor of the ovens, is an 'apron' of stone and brick masonry, eight feet wide and running the entire length of the battery.

"Four feet below this masonry or apron, is another piece of masonry seven feet wide, which also runs the entire length of the battery on which the truck of the 'dinky' containing the machinery for drawing the coke is located.

" Still further below is the railroad track, on which are placed the cars for the receipt and shipment of the coke.

" At the rear of the battery is another track, on which runs a car used for conveying the 'drag' from oven to oven, and on this car is permanently fixed a crab for pulling the drag back after discharging.

" Twelve tons of coal are charged from two six ton larries, through the funnel heads, as shown in the sketch, and the levelling is done from both ends.

" When ready to 'draw,' the doors at both ends of the ovens are swung open and an iron rod passed through the oven over the top of the hot coke, and attached to the drag at the rear. The hot coke is thus drawn in a body out of the front end of the oven, and over a screen attached to the dinkey, at which point the fire is quenched with water falling from a tank, situated above the screen, (no water whatever being thrown into the oven). From the screen it falls in broken pieces to the railroad car below and is ready for shipment."

The yield is practically the same as from the Bee-Hive ovens under skilful management, and the quality of the product, so far as can be determined by analysis and observation, is fully up to the standard. I regret that I cannot present data showing its relation to the Bee-Hive coke in furnace practice, but the conditions of consumption are such that it has not been practicable to made such a test.

The claim for economy in reducing the labor in making coke in this oven, requires more data to define the exact amount. The relative original costs of this and the Bee-Hive oven, to produce a given output per month, with the costs of repairs of each kind of oven, should have been submitted, in order to have a fair comparison of merits.

It will readily appear that in all these ovens, with admission of air through doors, or by special ports, the true principle of coking is retained —freedom of the coal, by the shallow charges, to develop the best physical structure in coking, as the pressure of these coal charges, in these broad horizontal ovens, is so slight as not to materially compress the fusing mass in forming the cells in making coke. On the other side, there is some waste by the admission of air in burning the expelled gases in the crowns of the ovens above, and in contact with the coking coal.

This is all that can be urged against the use of these types of coke ovens, in the manufacture of coke. With care in cooling the coke, especially when watered in the oven, a product is obtained in best condition for affording the utmost calorific energy in metallurgical operations.

THE McLANAHAN OVEN.

In the year 1875, Mr. J. King McLanahan designed a coke oven after the general principle of the Welsh oven, somewhat enlarged and greatly improved, especially in its details. It has also flues and an improved steam ram for discharging the coke from the oven.

The flues were designed to meet the requirements of coals low in hydrogenous matters, so as to economize the heat of the gases expelled in coking.

The accompanying plan, cross section, and longitudinal section, Fig. 40, will show the general arrangements of the "Composite" plan of coke oven.

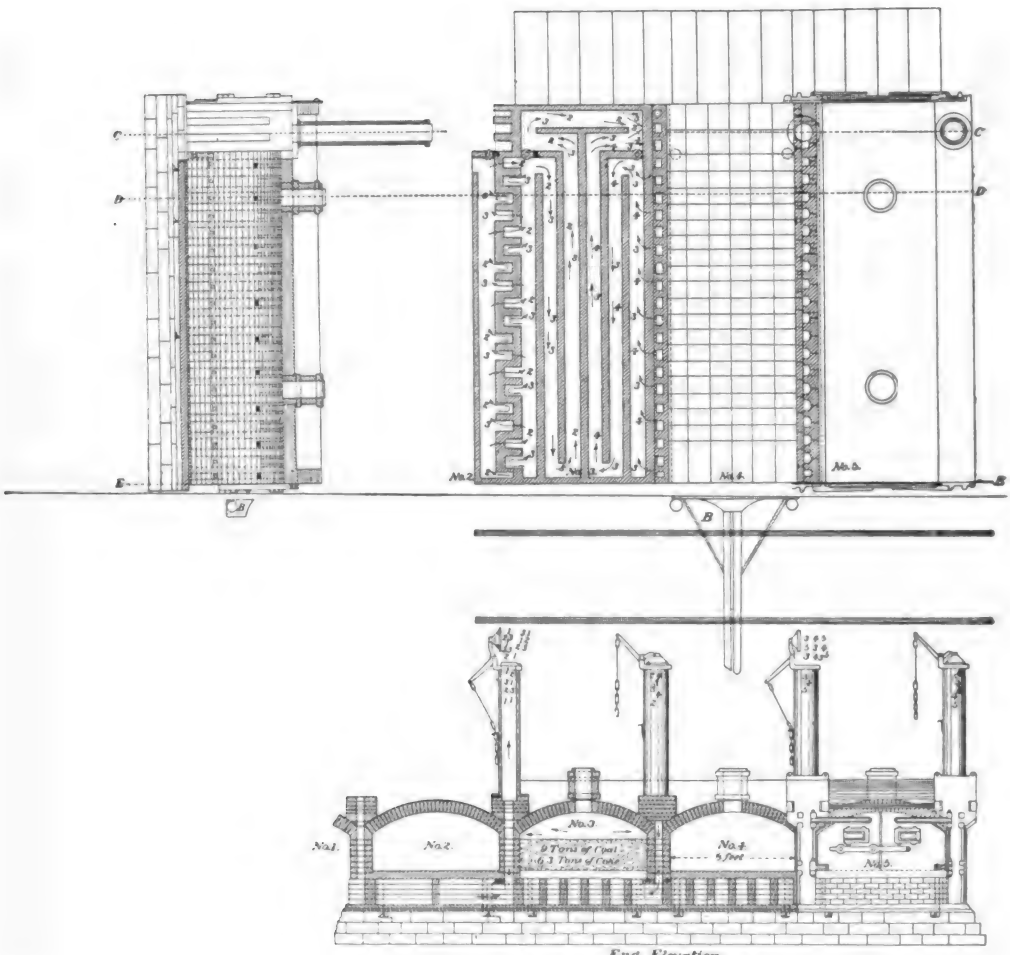


Fig. 40.—J. KING McLANAHAN'S COMPOSITE COKE OVEN.

REFERENCE.

No. 2 End elevation, Section through *C-C* of Plan.
No. 3. End elevation, Section through *D-D* of Plan.
No. 4. End elevation, Section through *E-E* of Plan.
No. 5. End elevation, Showing Doors and Binders.
A-A. Flues Admitting Air to Combustion Chamber.
No. 3.′ Plan of Flues under Coking bottom and foundation of partition Wall.
No. 4. Plan Section through *H-H*.
No. 5. Plan of Top of Arch.
B. Pusher-Head.

The oven is 8 feet wide, 24 feet long and 4 feet high to crown of arched covering. It is designed to receive a charge of coal of 9 tons, producing 6.3 tons of coke in 48 hours.

An appliance, operated readily, has been tested for leveling the charge of coal in the oven.

It will be seen that this plan of oven is very complete in all its details, preserving the true principle in the manufacture of coke, and reducing the expenses of drawing the coke and leveling the coal charged.

The coke can be watered or quenched inside or outside this oven. The latter method should only be used when the dry quality of coal requires the sustained heat of the oven to assure the best results in coking.

Coking coals having ample volatile combustible matter, that contribute to the fusion in coking, will bear the slow action in an oven that has been cooled somewhat in quenching the coke inside of it; but coals with small volumes of fusing matter require prompt heat treatment to fix or fuse the little they have, and to prevent its volatilization by slow heat.

A more recent design for a coke oven, by Mr. McLanahan, is exhibited in Figs. 41 and 42.

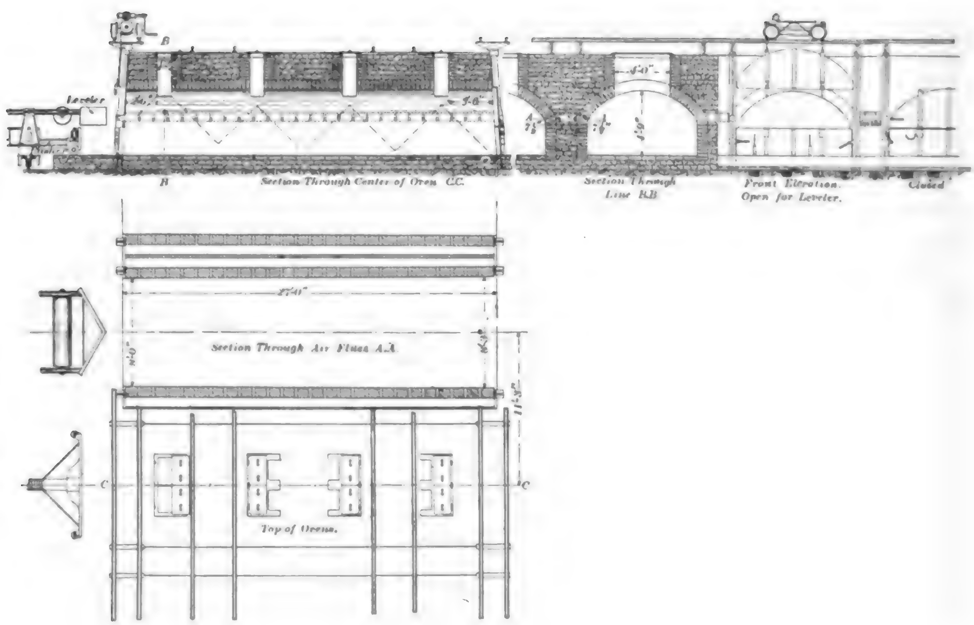


FIG. 41.—McLANAHAN COKE OVEN.

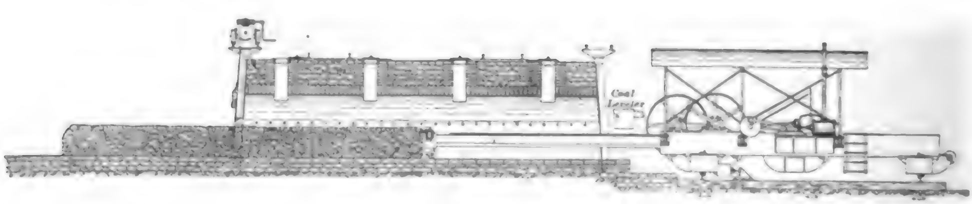


FIG. 42.—McLANAHAN COKE OVEN.

This oven is an enlargement and an improvement of the Welsh or Thomas oven.

It has a chamber 27 feet long, 8 feet broad and 4 feet 9 inches high, from floor to crown of arch.

It has annular air supply flues *A A*, with mechanical appliances for opening and closing the large doors of the oven, and a steam ram or pusher for discharging the coke. The coke can be watered or cooled inside or outside this oven at pleasure.

The coal is charged into the oven from larries through four ports the leveling being performed by a special attachment to the pusher, which accomplishes this work in a very expeditious manner.

It will readily appear that this plan of coke oven secures by its shallow charge, in its wide chamber, full freedom for the development of the cells, assuring the best possible physical structure of the coke for metallurgical uses.

The admission of air by the annular flues, above the charge of coal, supplies sufficient air for mixture with the gases to assure perfect combustion under the arch of the oven.

The mechanical leveler and discharger assure the utmost economy in these operations.

With good coking coal this type of coke oven should afford excellent coke at a moderate cost in its manufacture.

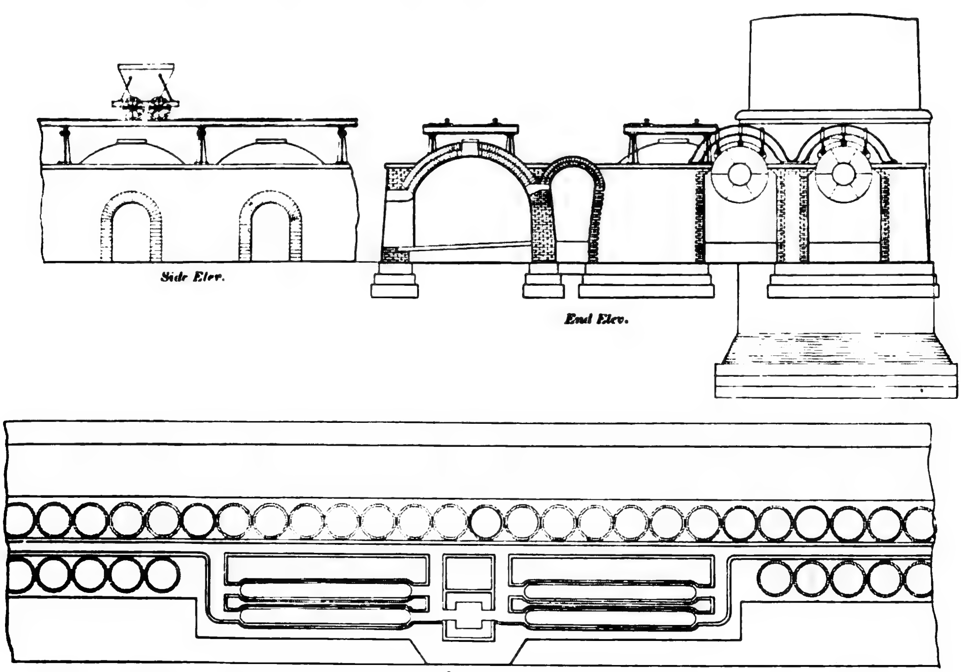


FIG. 43.—PLAN OF BROWNEY COLLIERY COKE OVENS AND BOILERS.

Desiring to learn the condition of the Bee-Hive coke oven, in the celebrated Durham coal district in England, and to be advised as to the progress of the introduction of the narrow or retort coke oven there, with the status of efforts in the saving of the by-products of tar and sulphate of ammonia, I wrote Sir Isaac Lowthian Bell, the eminent authority on all matters connected with the iron and steel industries, who kindly sent the drawings shown in Fig. 43, of the Browney colliery coke plant of Messrs. Bell Brothers,* with the following note covering my inquires:

ROUNTON GRANGE, Northallerton, May 22d, 1893.

My Dear Mr. Fulton:

Various circumstances, my own engagements not being the least, have conspired to delay my reply to your letter of 10th ult.

I enclose the tracing of our own ovens, by means of the waste heat of which we supply our collieries with steam power. In these by-products are wasted, as you no doubt will see. It is difficult, I may say impossible, to give a categorical reply to your enquiry in respect to the narrow ovens in which combustion *in* the ovenself is avoided and where in consequence ammonia and tar escape decomposition. In certain districts, even in England, they are successful, the difficulty being their maintenance in good repair.

In South Wales they seem to do very well; with us, in the County of Durham, and in Yorkshire, the reverse has frequently been the result. My own opinion is that the richness in combustible gas lies at the root of the evil, the consequence being an elevation of temperature in the outside flues which is incompatible with stability.

My own firm has spent large sums in pursuit of a plan of obtaining ammonia, &c., and the firm of Messrs. Pease & Company are continuing the process with perfect success as regards the by-products, but they, or their customers, find, as we found, the coke not so suitable for blast furnace work as that burnt in the old fashioned Bee-Hive oven.

I am very sorry that I find it impossible to see your Exhibition at Chicago. I must therefore be content to hear what others have to say on the subject.

With my kindest regards to all my good and faithful friends in Johnstown, believe me yours faithfully,

I. LOWTHIAN BELL.

I enclose a letter also from our Engineer, Mr. Steavenson.

Mr. Steavenson's letter reads as follows: "By the narrow ovens I presume Mr. Fulton means those which are discharged by ram and cooled by water outside; this we have always found causes an excess of moisture amounting to 4 or 5%, whereas with the round oven it does not exceed the half of 1%, when cooled before being drawn.

If the narrow ovens are burned close so as to produce by-products, it gives a solid lumpy material which works badly in the blast furnace.

Messrs. Newton, Chambers & Company, of Sheffield, say they are successfully drawing off the by-products from the floor of the open burning Bee-Hive oven; this may depend upon their having an open free burning coal, but we have not yet succeeded in doing it with the rich burning coal of Durham, and when we get 64% of good coke and all the steam which is required for drawing 1,000 tons per day, and pumping a large feeder of water from 600 feet, we seem to have accomplished a fairly satisfactory result.

A. L. STEAVENSON.

* The chimney for these ovens, the base of which is shown in the end elevation, Fig. 43, extends 80 feet above the top of the ovens, and is battered 1 in 27.

From the arrangements of the Bee-Hive coke ovens of the Messrs. Bell Brothers, England, it will be seen that the hot gases from these ovens are conveyed through a central conduit and carried under boilers, affording steam for winding coal, pumping water and other uses.

Similar applications of the waste heat of coke ovens have been made in Scotland and on the continent of Europe.

In America these waste gases have been utilized at a few plants, in a similar service—generating steam. Mr. E. Ramsay, Mining Engineer of the Tennessee Coal, Iron and Railroad Company, describes in a paper read before the Alabama Industrial and Scientific Society, the method in use at the Pratt mines.

"In order that the construction and mode of operation of the plants now in operation may be readily understood, I have prepared plans of one of the plants to which reference will be made in this paper, Figs. 44 and 45. As noted heretofore the ovens from which the gases and heat are derived, were built some years ago and were in operation at the time work was commenced. The first part of the work undertaken was the construction of the longitudinal main flue which is cylindrical in section and placed immediately to the rear of the ovens. A few ovens were blown out at a time and as the flue was built and connection made to each oven, these ovens were again put in blast and others blown out, and so on until the flue had been built and connections made to the entire battery of 25 ovens. This main flue is 3 feet 6 inches internal diameter, has 4-inch walls on bottom half and 9-inch walls on top half and is built of fire brick furnished by the Bessemer Fire Brick Company, of Bessemer, Ala. At first thought it may seem that the walls are too light for a flue of such diameter, but when one reasons that this flue is cylindrical in shape, which gives the greatest possible strength for the amount of material used, the objection does not have the same force. At all events it has given no trouble except on two occasions when a few bricks fell out of the walls and into the flue at the juncture of one of the small flues which connects it with the ovens. When the clay and earth filling was removed from the rear of the ovens to make room for the main flue, it was found, as was expected, to be quite hard burned and especially that part resting on the oven walls proper, which was as hard burned as an ordinary red brick. This hard material was nicely cut out to a section equal to the half circle of the external diameter of the flue, the bottom half of which was laid in it, using the cut out section as a form, and a loamy clay as mortar. The upper half of the flue was then laid, using the ordinary wood centers, which were moved along as the flue was completed. Over the upper half of the flue, a layer of about 6 inches thick of well puddled clay was put on, which, when the heat was turned on, was burned into the hardness of a red brick. This plan was adopted as a cheap means of reinforcing and adding strength to the walls of the flue, and making it so that if a brick or two did fall out, it would be quite probable the

flue would continue to do duty until a convenient time for making repairs could be had. In both of the instances where the flue gave way, work was continued for several days before repairs were made. As is shown by the plan, in transverse and longitudinal sections, the main flue is built in contact with the rear walls of the ovens and a connection is made to each oven at the point of contact by a cylindrical fire brick flue 12 inches in diameter and about 20 inches long.

"There are two boiler plants of the design, size and construction shown in plan, in operation at Pratt mines, and each one receives the heat and gases from its individual battery of 12-foot bank Bee-Hive ovens of the usual American construction. Each plant consists of two batteries of 46-inch by 26-foot boilers, with two 16-inch flues each, and is situated midway and to the rear of the ovens in such a position that the transverse center line which passes through the center of the thirteenth oven, counted from either end, is also the center line of the boiler plant. The boilers were placed in the center of the bank of ovens for the reason that the closer they were placed to the ovens the less the distance would be which the gases would have to travel, and, consequently, the less would be the loss of the initial heat of the gases by radiation. To illustrate: the boilers might be placed so far from the ovens as to cause the gases to part with all the initial oven heat before arriving at the boilers, and in such a case the benefit derived would be alone in the combustion of the gases at the boilers, with the proper admixture of air, in a manner similar to the burning of gases from the blast furnaces under boilers and in hot blast stoves. This being the case it is apparent that unless the conditions will not admit of it, the boilers should be placed as close to the ovens as possible. The boiler settings, as will be seen from the drawings, are of the ordinary type, with the boiler fronts and grate bars omitted. To have used grate bars, in order to allow of hand firing with coal, would have complicated the plant to an extent which the benefits to be derived would not have warranted. As noted in a previous portion of this paper, grate bars were used in the first experimental plant erected at Pratt mine, and in that case they were rapidly destroyed by the incandescent gases passing over them. To have obviated this trouble it would have been necessary to admit the gases back of the grate bars, and in such a case that part of the boiler immediately over the bars would have been practically dead space, or a furnace might have been built, to one or both sides of the boilers, in such a manner as to admit the heat and gases at the same point as they are now admitted in the plant described in this paper.

"In order that each battery might be worked separately, or both at one time, an independent flue from the main flue and discharging under the battery is provided, as shown in the plan, and in each of these branch flues, which are of the same diameter as the main flue, a damper was placed in the first plant built, but after working practically for several months it was found to be almost unnecessary, as the opening of the breeching and clean-

ing doors at once stops the draft, and, consequently, the flow of gases, and if the shut-down was to be for any length of time, it would be an easy matter to close one of the flues with a temporary brick wall, such as is used in closing coke oven doors at each drawing. That it is only a matter of a few minutes' work to open these doors and take off the oven dampers has been demonstrated on several occasions when it was desired to stop the flow of gas and heat to the boilers. In fact, this can be done as expeditiously almost as a damper large and unwieldy, as it would necessarily be, could be manipulated.

"The foregoing description, together with the accompanying plans, will, I hope, enable you, with but little trouble, to understand what the plant is like and how it is built and operated.

"The amount of steam actuated machinery at this mine (Shaft No. 1) is very large, and requires a great amount of steam for its operation. Before the utilization of the waste heat and coke oven gases in the making of steam, this plant used monthly about 1,500 tons of coal, or 7½ per cent. of the entire output of the mine for boiler use. This, at $1 per ton, represented a monthly loss of $1,500 for boiler coal, or about 7½ cents per ton of coal on the entire output. As long as the selling price of coal was reasonably remunerative, this large outlay for boiler fuel was not felt so much, but as the selling price constantly became less and less, it was imperative that something should be done. Then work was commenced on the boiler plants at the bank coke ovens, and so successful has been their operation that the coal used at the old boilers has been reduced to 300 tons per month. When the amount of labor used at the coal fired boilers for firemen and ash wheelers, together with the expense of grate bars and general wear and tear is considered, it is no exaggeration to say that the coke oven boilers have effected a monthly saving of $1,500 or $18,000 per annum. By utilizing the gas from another block of 25 ovens the entire plant could be supplied with steam without using any coal whatever, except a little on Monday mornings, when the ovens are cold from standing over Sundays; and even this could be obviated by drawing and charging a few of the ovens on that day."

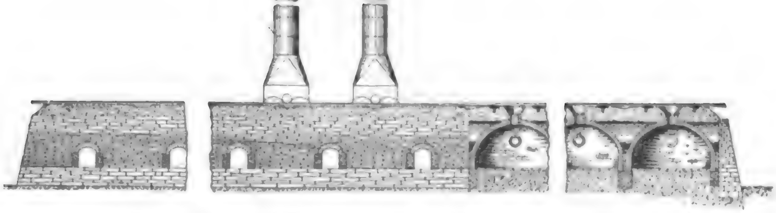


FIG. 44.—FRONT ELEVATION AND LONGITUDINAL SECTION.

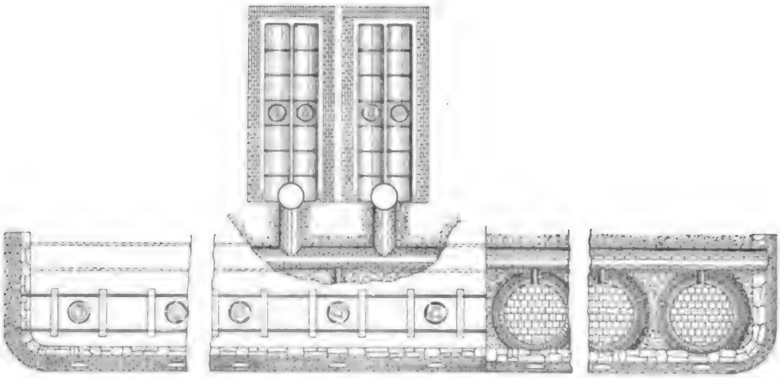


FIG. 45. TOP VIEW AND HORIZONTAL SECTION.

From the evidence of the economy in these methods of utilizing the waste gases from plants of Bee-Hive coke ovens, in affording heat for generating steam, it is evident that it will be well to consider these examples on the lines of economy, especially in erecting new plants of coke ovens.

CHAPTER V.

THE RETORT AND BY-PRODUCT SAVING COKE OVENS.

Early Efforts at Saving By-products.—First Ovens, 1766.—Slow Progress in this Effort.—The Initial Oven Designed and Built by Knab in 1856.—This Afforded a Reliable Example.—Jones and Blackwell's Patent, 1861.—Simon-Carvés, France, Improved the Knab Plan of Oven.—Hüessner's Successful Oven in 1881.—G. Seibel Oven.—Founded on True Scientific Principles.—Otto-Hoffman Regenerative Oven.—By-Products.—Attention now Given to Dimensions of Ovens for Coking the Several Varieties of Coals.—Early Retort Oven Coke Regarded with Disfavor.—Hoffman and others Removed this Doubt.—Aitken Experiments on Bee-Hive Coke Ovens in Scotland for Securing By-Products.—In England, Jamison took up Similar Work.—In 1880, Simon-Carvés Introduced this Oven into England.—Growing Market for By-products Induced by Change in Method of Making Illuminating Gas.—The Belgian Coke Oven and its Work.—The Coppée Coke Oven and its Product.—The Appolt Coke Oven.—A New Design.—Modified Appolt Coke Oven.—Analyses of Appalachian Coals.—Alaska Coals.—Belt Mountain Coals.—Simon-Carvés Coke Oven.—Cost.—Product.—Seibel's Retort Coke Oven.—Its Products.—Otto-Hoffman Retort Oven and its Work.—Cost.—Value of By-products.—Dr. Bruno on Dr. Otto's Plan for Saving By-products in the Bee-Hive Coke Oven.—Festner-Hoffman Coke Oven.—Henry Aitken's Oven, Scotch.—The Semet-Solvay Oven With its Operations at Syracuse, New York State.—The Bernard Coke Oven, Nova Scotia.—Constructed by Mr. Walter M. Stein, Philadelphia.—Elliptical Bee-Hive Oven.—A. D. Shrewsbury Coke Oven.—Regenerative Coke Oven.—Bee-Hive Plan.

THE INITIAL AND MODERN COKE OVENS—WITH AUXILIARY APPARATUS FOR SAVING THE BY-PRODUCTS OF TAR AND AMMONIA.

The efforts for supplementing the profits of coke making, by saving the by-products of tar and ammonia from the gases discharged from the coke ovens, occupied the early attention of coke manufacturers.

Evidently this new departure was suggested to coke makers and oven builders from the operations in the manufacture of illuminating gas; the gas makers, in the process of purifying this product, required the elimination of tar and ammoniacal water.

It thus became evident to coke makers, that the gases evolved from the coke ovens contained similar products, and logically suggested additional profit in saving them.

It is recorded that the first coke ovens producing tar and ammonia as

by-products, were constructed at Sulzbach, near Saarbrücken, in 1766. These first attempts were very crude and of little practical value.

In 1781, Sir Archibald Cochrane, Count of Dundonald, obtained a patent on the production of tar, volatile oils, alkalies, acids, pitch and coke, from bituminous coal.

Very slow progress was made in the saving of by-products; their practical manufacture and sale in market was not assured until about the year 1883.

The reason of this slow progress has been attributed to two principal causes; the low price of these products in market, from the supply of the gas works, under the method in use until recently, of making illuminating gas from bituminous coal; besides, the early efforts at the coke works were expensive and unsatisfactory, both in quality of coke and value of by-products secured.

In 1856, Knab, of the Department Allier, France, built a group of retort coke ovens, in which a double purpose is evident; the saving of the by-products of tar and aqua ammonia and the manufacture of illuminating gas. The gases freed from tar and ammonia were returned to the ovens and burned in the flues to reinforce the heat for coking.

These ovens are described as having narrow vertical chambers, 23 feet long, 6 feet $6\frac{3}{4}$ inches high and 3 feet $3\frac{1}{3}$ inches wide. They were also provided with bottom draught.

The principal difficulty in extending the use of these ovens, and which has only recently been corrected, consisted in the neglect of proportioning the several parts of the oven to the requirements of the quality of the coals to be coked.

With the advent of correct dimensions in the retort coke ovens, to meet the wants of the various qualities of coal, their increased use in the manufacture of coke and saving of by-products, has been largely extended.

Jones and Blackwell took out patents in 1861 to produce tar and ammonia by converting coal into coke in kilns, but the experiment failed.

In 1862, Simon and Carvés, of France, made very valuable improvements in the original plan of the Knab oven.

They introduced side horizontal flues in addition to the bottom flues in the Knab oven. The gases from this closed oven were drawn out to condensers and scrubbers by an exhaust engine, the tar and ammonia separated and the remaining gas returned to supplement the oven heat.

The construction of this Knab-Carvés coke oven, with important improvements in 1873 to assure the better distribution of heat, afforded a model for subsequent coke ovens.

This was soon appropriated by Albert Hüessner, who is credited with the practical introduction of a successful oven and apparatus for securing by-products from the coke oven gases.

Hüessner built 100 ovens in 1881, establishing the by-products industry on a sound basis in Germany.

The quality of the coke, however, made in these ovens was regarded as inferior on account of the rapid exhaustion of the gases by suction, and it required many years with considerable improvements in the ovens to overcome this objection.

The G. Seibel coke oven was introduced in France in 1881.

It has horizontal flues in the middle of the walls of the coking chambers, with gas reservoir after the Simon-Carvés plan.

It was the first oven built for saving by-products without grates.

At one plant in France the surplus gas, after the extraction of by-products, is used for illuminating purposes.

The temperature obtained in this oven is fully equal to the Otto-Hoffman oven with its expensive regenerators.

The main element in the design of this oven, is, to maintain the process of coking so successfully in use in the Bee-Hive ovens; that is, the carbonization of the charge of coal in the oven, beginning at the upper surface and going downward to the bottom of the oven, proportioning the heat as the coking progresses downward from top to floor of oven.

This secures the deposition of the maximum quantity of carbon, from the evolved hydro-carbon gas from the coal in coking.

About 11 per cent. of deposited carbon has been secured under this method in this coke oven, which not only glazes the coke with nearly pure carbon, but also adds very materially to the percentage of the carbon in the coke, reducing, relatively, the ratio of impurities to the carbon in the cokel

The principles under which this oven was designed by Mr. G. Seibe. are undoubtedly correct, and should afford excellent results in the quality of coke and saving of by-products.

About this time the earnest attention of coke manufacturers was directed, from previous experience, to two prime requirements in the production of coke and securing by-products.

The first consisted in the necessity of proportioning the size of the oven chamber to meet the requirements of the different qualities of coking coals ; the coals rich in volatile matters requiring treatment in wider ovens, whilst the "dry" coals or those low in volatile matters demanded narrow ovens for the best products in coke.

The previous inattention to these prime requirements, especially in coking the continental coals of Germany, Belgium and France, caused the retort cokes to be regarded with suspicion, as to their adaptability for producing coke for metallurgical purposes. It required considerable time to remove this prejudice.

The ultimate credit of doing so is attributed to Dr. C. Otto and Co., of Thalhousen on the Ruhr, who in 1881, erected 10 trial ovens which laid the foundation of a system coming into favorable use. But it required the addition of the Siemens' regenerator, in order to heat the air, required for the complete combustion of gas, to as high degree as possible, before a successful condition was assured.

This addition was patented by Gustave Hoffman in 1883, constituting the "Otto-Hoffman" coke oven.

Some criticism has been made questioning the value of the addition of the Siemens regenerators to the Otto-Hoffman oven, with the increased cost involved by these appendages.

The arrangement of vertical side flues is also regarded as objectionable, from the difficulty of distributing the heat evenly, with the reduced amount of it secured.

This Otto-Hoffman coke oven was further improved by E. Festner, of Gottesburg, who made an important change in the position of the flues, in the oven side walls, by using the horizontal in place of the vertical position. He also abandoned the Siemens regenerator, replacing it with the Ponsard gas furnace.

In establishing these improvements he is reported as having the co-operation of Hoffman. This oven has been named "The Festner-Hoffman" coke oven.

The Semet-Solvay oven came into appreciative notice in 1887.

It is designed for coking "dry" coals, or a mixture of "pitchy" and dry coals. Its side walls are made with flued and jointed tiles in horizontal posture. This secures a maximum heat, which can be evenly distributed so as to avoid the destruction of fire brick lining by concentrated heat at certain localities.

The dimensions of this oven are made to meet the requirements of the several qualities of coking coals, or mixtures of such coals.

It has two simple "heat reservoirs" and avoids the rather expensive "regenerators" and "recuperators" of some other ovens.

It is usually regarded as a plain economical oven, well adapted to the saving of by-products.

In Scotland, Mr. Henry Aitken of Falkirk introduced important improvements in the method of coking in the Bee-Hive oven, and subsequently added appliances for the saving of by-products from the gases of this oven.

The first improvement of 1874 consisted in the application of hot air into the dome of the oven, so as to increase the heat by the thorough combustion of the gases evolved from the coking coal beneath. This augmented heat supply was designed to save the burning of the fixed carbon in the coking coal. In 1880 he made further progress by introducing apparatus for the saving of the by-products in the Bee-Hive ovens.

This consists in the placing of a triple radial perforated conduit in the bottom of the oven, connected with exhaust pipe leading to condenser and scrubber, to secure the by-products.

These inventions were quite successful, and approached, at the time, very nearly to the best results in retort oven practice.

In England, in 1883, Mr. John Jamison devised methods very similar to Aitken's for saving by-products in coking in Bee-Hive ovens. He intro-

duced no change in the form of the ordinary Bee-Hive oven, except to place channels or conduits in its bottom, through which to extract the gases of of carbonization by a slight suction exhaust.

He has obtained in this way good results in both coke and by-products.

Simon and Carvés introduced in England, about the year 1880, their improved retort, recuperative coke oven, bearing their names.

This plan is a decided improvement of the Coppée model in simplicity of design and efficiency in work, but the Coppée oven afforded the base for the Otto-Hoffman and the Simon-Carvés.

It has horizontal flues with attached apparatus for securing the by-products.

This plan of oven has been quite successful in producing a large percentage of good coke at a moderate cost.

In Great Britain, with its excellent coking coals, the continental retort oven was slow in finding general favor.

This condition existed from the fact that the Bee-Hive oven produced excellent coke for metallurgical purposes. The small wastage of carbon by this method was not regarded as of prime importance, as it was urged that the physical structure of the coke made in the Bee-Hive oven, under slight pressure, developed a cell structure that conferred superior calorific energy on this kind of coke. And it was further submitted that the smaller product of the Bee-Hive oven, in blast furnace use, was equal to the work of the larger product of the denser retort coke.

Doubtless, in the early efforts in the introduction of the retort coke ovens, the importance of proportioning their several parts for the coking of coals of different qualities was not so well understood as in more recent times. Besides, the value of the by-products from the coke ovens was not considered in a manner commensurate with its importance.

In the United States of America, with its great coal fields, embracing so large areas of excellent coking coals, the introduction of retort coke ovens has been slow.

This arises mainly from the large cost of these ovens, especially when when supplied with an equipment for saving by-products.

A secondary hindrance consists in the expensive labor cost in small experimental plants. A maximum number of coke ovens are required to assure minimum cost in the labor of coke making.

However, since the decline of the production of tar and ammoniacal liquor in the gas works, the by-products from coke works have realized a revival of their importance, especially the sulphate of ammonia as a valuable farm manure, which in the progress of improved agricultural operations, is coming largely into demand.

These have given retort coke ovens renewed attention and importance.

This will be further reinforced as the use of coke enlarges, requiring the use of some of the secondary qualities of coals to maintain the necessary supply of this valuable metallurgical fuel.

As a sequence of the requirements of coke manufacture on the continent of Europe, demanding for successful treatment the use of the closed or retort coke ovens, the auxillary apparatus for saving the by-products was adjusted to these types of ovens, and some ovens were designed with a view mainly for the securing of the by-products.

In Great Britain, with the satisfactory Bee-Hive oven coke manufacture, the appliances for saving the by-products had their first application on this plan of oven, graduating in recent years to the retort type of coke ovens.

In the European countries the sulphate of ammonia, as a manure, has received careful attention, as this salt is an excellent fertilizing agent and is largely used in farming operations.

The tar affords elements that are widely used in many of the industrial arts.

The large areas of superior coals for making coke found in the United States and in Great Britain afford the best metallurgical coke in the Bee-Hive oven.

This condition, even with its expensive labor and waste of fixed carbon, restrained efforts in improvements in the coke oven, except in the single direction of economy in the labor of drawing the coke from the oven by mechanical appliances in place of manual labor, as noticed in the instance of the Welsh coke oven.

But in Belgium the conditions are quite different. The coals there are poor in quality and low in the elements that fuse the coal in coking.

In this busy little kingdom, with the expanding use of coke, it early became a very urgent requirement to devise ovens to coke their inferior coking coals.

The "Belgian coke oven" was the result of efforts in this direction. It was followed by a number of ovens of similar construction bearing its name.

The Belgian oven was succeeded by a large variety of closed or retort ovens in Germany, Belgium, France, and recently in England.

As we shall consider these ovens in their proper order, we will endeavor to unfold the main designs of their authors in each plan of oven.

It may be submitted here that the chief and imperative requirement in all of these ovens, is the economy of heat in the operation of coking.

To satisfy this prime demand, passages and flues have been introduced in the bottoms and walls of the ovens, to utilize the heat of the gases expelled from the coal in coking, returning it through these passages and flues to maintain the necessary oven heat in coking.

During the past decade auxiliary apparatus has been attached to some of these ovens, and has been successful in saving the chief by-products of tar and sulphate of ammonia, from the gases evolved from the coal in coking.

After these by-products have been secured, the gases are returned to regenerators and used in the usual way in heating the coke ovens.

Any surplus heat from these gases is frequently utilized under the boilers in making steam.

THE BELGIAN OVEN.

The Belgian coke oven was evidently designed to satisfy three principal requirements:

First.—To meet the condition of coking coals of inferior quality, requiring the economy of heat from the gases by returning them under and around the coking chamber of the oven, through passages and flues, and to retain the oven heat by the rapid discharge of the coke, cooling it outside the oven.

Second.—In the economy of the work of drawing or discharging the coke from the oven by mechanical appliances, in place of the rather slow and expensive methods of performing this work by manual labor.

Third.—Excluding the air in coking the coal as much as practical, so as to save the waste of fixed carbon usually made in ovens admitting the admixture of air in the coking chamber, and in affording an increased percentage of coke from the coal charged in oven.

The inferior dry coals of continental Europe could only be coked to best advantage in closed ovens.

It involves, however, the necessity of cooling the coke outside the oven, leaving in this coke 4 to 8 per cent. of moisture, under ordinary conditions.

Whether the increased product of coke, from the coal charged in these ovens, will compensate for the augmented moisture in the coke, from the necessity of watering it outside the oven, will be considered hereafter in detail.

On the other side, by this rapid discharge of coke, the oven heat is retained and acts quickly on the newly charged coal, utilizing the small volume of fusing matters in the dry coals.

The accompanying drawing, Fig. 46, will show the main features of the early Belgian coke oven. References to its parts are given on the drawing.

Its general design consisted in the economy of heat, in coking the inferior dry coals.

The width and height of this oven chamber were usually proportioned to meet the requirements of the coals to be coked. The dryer the quality of the coal, the narrower the chamber of the oven. And conversely, the oven was made wider when coals inheriting more hydrogenous matters were to be used in coke making.

During the working of the bank of Belgian coke ovens, by the Blair Iron & Coal Company, at Hollidaysburg, Pa., the coal used was from the Miller (B) Seam in the Bennington Mine. It was composed as follows:

Volatile Matters	22.38
Fixed Carbon	68.50
Ash	8.00
Sulphur	1.12
	100.

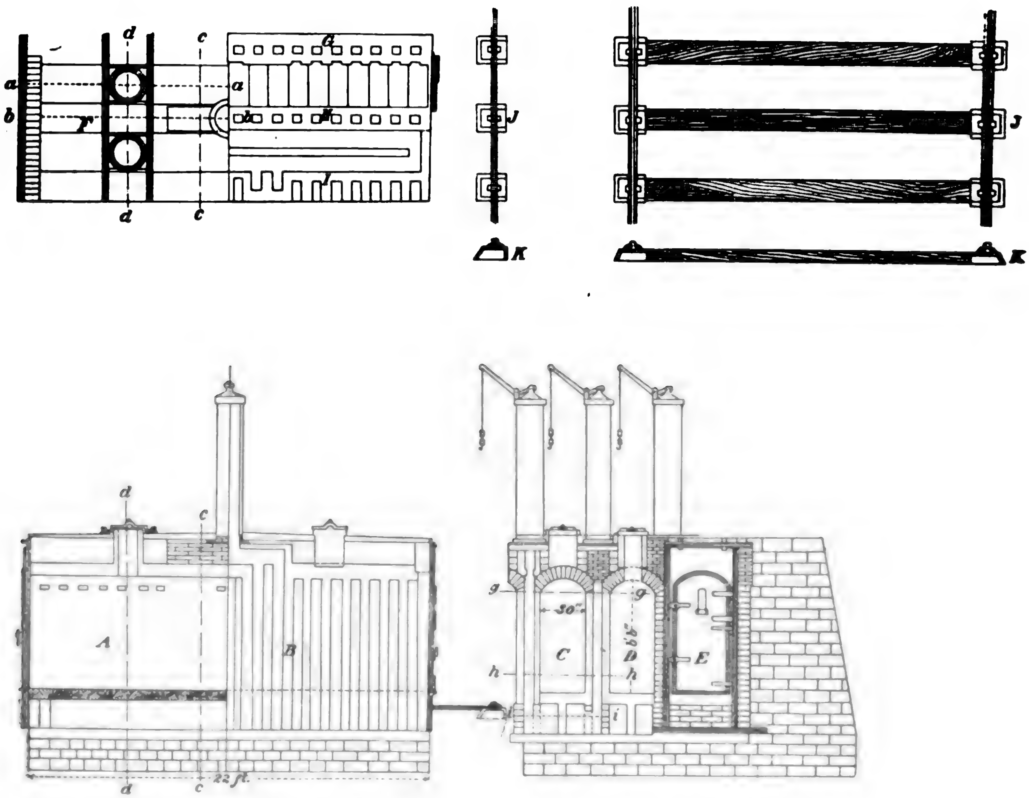


Fig. 46.—ORDINARY BELGIAN COKE OVEN.

Scale $\frac{3}{32}$ in. = 1 ft.

REFERENCE.

- *A.* Section through *a-a.*
- *B.* Section through *b-b.*
- *C.* Section through *c-c.*
- *D.* Section through *d-d.*
- *E.* End Elevation.
- *F.* Plan of Top of Ovens.
- *G.* Plan of Section through *g-g.*
- *H.* Plan of Section through *h-h.*
- *I.* Plan of Section through *i-i.*
- *J.* Plan of Pusher Track.
- *K.* Elevation of Pusher Track.

The theoretic coke from the above coal, assuming 40 per cent. of the sulphur to have been volatilized in coking, is 77.17 per cent.

The Belgian coke ovens, using this Miller coal, gave the following results:

Coal charged	6.86 gross tons.
Coke made	4.81 gross tons.
Difference	2.05 gross tons.

The oven yield of coke was, therefore, 70.12 per cent. of coal charged, requiring 1.42 tons of coal to make 1 ton of coke. The loss of fixed carbon was 9.15 per cent.

In the large bank of Belgian ovens, formerly in use at the blast-furnaces of the Cambria Iron Company, at Johnstown, Pa., and using the Miller seam coal, the yield of coke was 70.3 per cent. indicating a loss of fixed carbon of 11.68 per cent.

This coal was washed in preparing it for coking in these ovens.

At the Bennington bank of 100 Bee-Hive coke ovens, using the Miller coal (B), from the same mine and of similar quality as formerly supplied to the Belgian ovens at Hollidaysburg, the product gave an average yield of coke of 64 per cent., requiring 1.56 tons of coal to make 1 ton of coke.

As previously shown, this coal affords 77.17 per cent. of *theoretic* coke.

The Bee-Hive ovens yield 64 per cent. of coke, showing a loss of fixed carbon of 17.06 per cent.

Equating the relative conditions of moisture in the Belgian oven, coke watered outside the oven, and the dryer coke of the Bee-Hive oven, watered inside it, the increased yield of coke from the Belgian over the Bee-Hive oven is about 10 per cent.

The modifications and additions to this family of coke ovens are quite numerous; even a brief description of their various forms would exceed the limits of this work.

The main principles of the original Belgian oven have been retained in its successors, though not always bearing the family name.

The ovens selected for illustration and description will be taken from the most practical types for the manufacture of coke at this time, and also those specially designed for supplementary apparatus in saving the by-products of dry distillation in the coking process.

THE COPPÉE COKE OVEN.

This oven is also a Belgian invention and was in use on the continent prior to 1861. In 1873-4 it was introduced into England. It has also been used in a few localities in the United States.

The main principles embraced in the design of the Belgian coke oven are preserved in the plan of the Coppée oven. The latter is much more complex in its structure and operation than the former.

The accompanying plan, Fig. 47, and description will show the general design of this oven.

The Coppée coke ovens are usually built in blocks of 20 to 30 ovens. The plans and sections referred to in the following description embrace a block of ovens of 22, with draft chimney and other appliances.

Fig. 1 represents a longitudinal section passing through the middle of a side wall of an oven, on line *C D*, Figure 5.

Figure 2 shows a longitudinal section through the middle of an oven, on line *A B*, Figure 5.

The Figure 3 shows section passing through the middle of an end side wall, on line *E F*, Figure 5.

Figure 4 shows cross section and elevation, on line *Y Z*, Figure 5.

Figure 5 is a plan from the line *G V*, Figure 4.

The courses of the gases are shown by plain arrows, whilst the way of air courses is shown by crossed arrows.

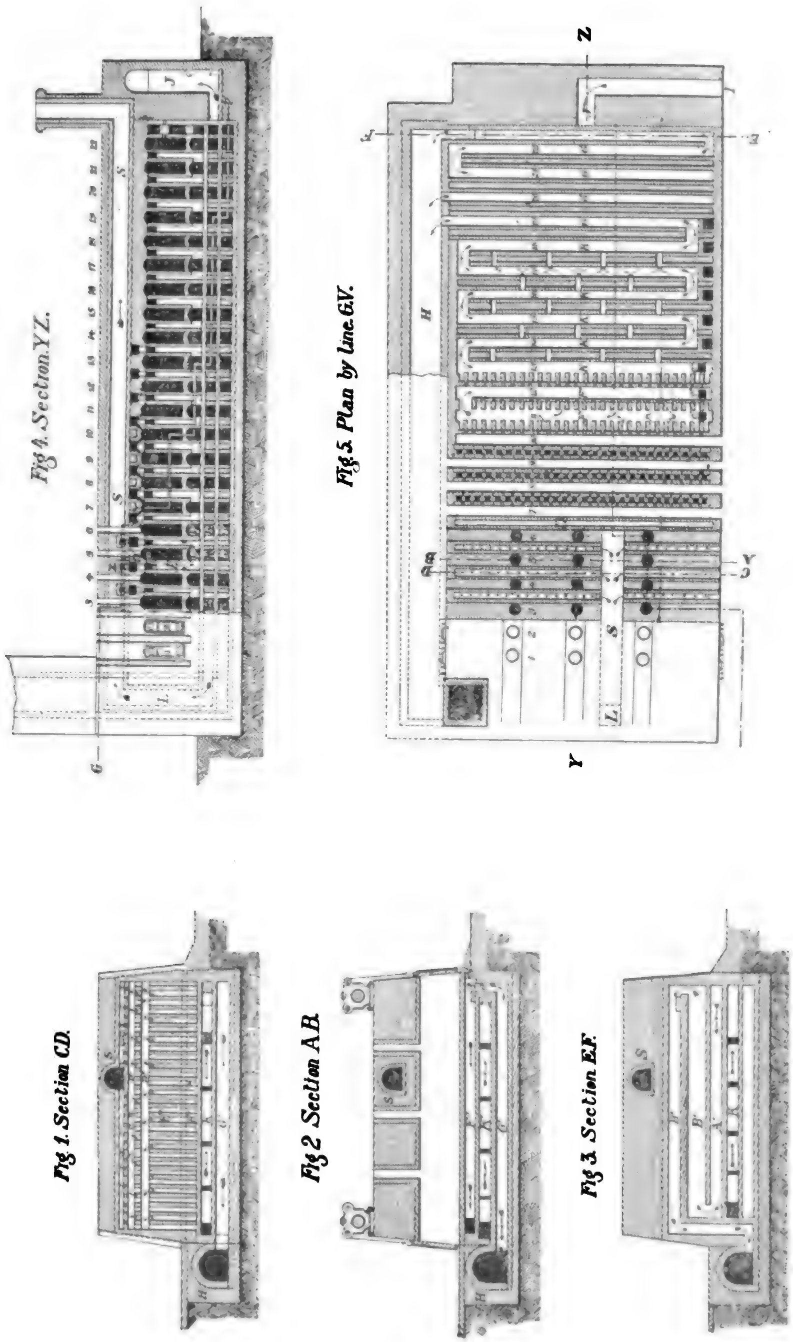


FIG. 47.—COPPÉE COKE OVEN.

The gas escapes from the oven through 28 openings A, situated on both sides of the oven, into the horizontal flue D', where it meets and mingles with the hot air brought by the flue S, and small flues X, X'.

The perfect combustion of the gases takes place in the horizontal flues *D'*, *D''*. The inflamed gases descend through 28 vertical flues *E*, into the flue *F'*, situated under the floor of the odd numbered oven; on this flue *F'*, the gases of the two side walls, communicating with the flue under the floor, mix together.

The gases run from one end of the flue to the other in the flue *F'*, and then pass into the flue *F''*, situated under the floor of an even numbered oven; next the gases go through the opening *O'*, reach the flue *G''*, situated under the regenerating air flues, and ultimately flow into the main flue, *H*.

The main flue takes the gases to the boilers, or to the chimney as the case may be.

In the flues *F'*, situated under the floor of the odd numbered ovens, an opening *O'*. is provided with a damper which regulates the admission of gases into the lower flues, *G'* and *G''*.

The requisite air for the combustion of gases is taken from the outside by an opening, *I*, situated in the end buttress wall, then it descends to reach the regenerating flues, *K*, from one end of the batch to the other end of it.

These air flues are situated between gas flues, *F'*, *F''*, and *G'*, *G''*. The air which enters from the outside by the opening, *I*, leaves the flues *K* through the opening *L*, having been raised to a temperature of 600° to 800° F.

This hot air ascends the shaft *L*, and reaches the flue *S*, situated on top of ovens. Out of this flue *S* the hot air gets divided by the small flues *X'*, *X''*, situated above each side wall, into the flues *D'*, *D''*, also situated above the side walls, and immediately under the flues *X'*, *X''*.

The discharging of the ovens is made by a ram engine which pushes out the coke, first out of the odd numbered ovens, so that each newly charged oven finds itself between two others in full operation, therefore between two highly heated ovens.

These alternate new charges, generating gases at once and escaping on both sides through 28 openings, enter the flues *D'*, *D''*, mingling with the hot gases of the adjoining ovens and the hot air supplied through the flues *X'*, *X''*.

From the foregoing description of the operations of this oven, it is evident that in using very dry coals the alternate charging and discharging of the ovens is necessary to the diffusion and maintenance of the oven heat.

With coals richer in volatile combustible matters, the ovens could be drawn in sections, thus avoiding any injurious pressure on the walls of the ovens by the swelling of the coal in coking.

These ovens are usually constructed of such width and height as may be required in coking coals inheriting different volumes of hydrogenous matters, varying in width from 15 inches to 13 inches, with heights governed by the same elements in the coal to be coked.

It is claimed that the Coppée oven affords 70 to 83 per cent. of coke in Belgium, and 67 to 75 per cent. in England.

A bank of 30 Coppée coke ovens, formerly in use at the Conemaugh furnace of the Cambria Iron Company, constructed with some modifications from the foregoing plan, especially in the arrangements of the crown flues, gave the following results in their work in coking a moderately dry coal during the fiscal year 1886.

The amount of coal charged into the ovens during the year was 12,630 gross tons; the coke produced, 8,680 tons, exhibiting a product of coke, weighed after having been watered outside of the ovens, of 68.72 per cent.; using 1.455 tons of coal to make 1 ton of coke.

The coal used in these ovens was constituted as follows:

Moisture 212° F	0.56
Volatile Matters	17.70
Fixed Carbon	73.98
Ash	7.36
Sulphur	0.82
Phosphorus	0.006

The theoretic coke in the above coal is 81.84 per cent. As the product of the ovens gave 68.72 per cent. there has been a loss of fixed carbon of 16 %.

It may be noted that this coal is very low in its volatile combustible elements, requiring the burning of some of the fixed carbon of the coal to sustain the oven heat in coking.

This leanness of volatile hydrocarbons in the coals at the city of Johnstown is quite remarkable and exceptional, as the Appalachian coals, east and west of this belt, inherit normal volumes of these matters, with their usual increase westwardly.

The work of the old Belgian coke ovens on the dry coals at Johnstown, and the results at Hollidaysburg on the second quality of coking coal from the Miller (B) seam at Bennington, have been considered in a former section.

The average result of a full year's work of a bank of 30 Coppée coke ovens at the Conemaugh furnace, supplied with the dry coal from the Lemon seam in the Johnstown basin has also been submitted.

The use of all of these ovens has been discontinued some years ago, for reasons which could not be wholly attributed to the work of the ovens.

The full comparison of the economies of the open and closed ovens, with cost of construction and adaptability of plans for special coals, will be considered hereafter.

It is submitted as an established experience that the approximate chemical analyses of coals will not disclose their coking properties. It is therefore evident that in determining the type of coke oven, with the proportions of its chamber, walls, flues, etc., etc., the only safe plan is to have a

sufficient quantity of coal coked in the several plans of ovens, or tested in some reliable experimental plant.*

As the Appalachian coal field affords the greatest supply of coking coals, the careful study of the proximate analyses of these becomes of the first importance, so that the coke oven best adapted for the several varieties of coals can be intelligently selected.

In this respect it may be added that in coking the coals *low* in volatile combustile matters, in any type of oven, it will be found of great benefit to break the coal to such sizes as will conduce to the most economic results in fixing the fusing matters in the initial operation of coking.

The oven will also be required to be kept at a maximum heat when charging the coal into it. With the disintegration of the coal and the sustained heat of the oven, the small volume of fusing matters in the coal can be promptly fixed in the coke and its dissipation with the gases prevented.

With coal charged into the oven in large lumps, it is evident, that as the coking begins on the outside and moves slowly into the interior of the lumps, the gases in the central portion must be dissipated in more or less volume, depending on the dryness of the coal and the size of the lumps.

It is quite remarkable that the standard coking coal of the Connellsville region, is found in a long narrow synclinal strip, west of the Chestnut Ridge. It affords a coal with an average chemical composition between the rather dry coals to the eastward of it and the too bituminous coals westward.

ANALYSES OF APPALACHIAN COALS.

Coal Fields.	Moisture, 212° F.	Volatile Matters.	Fixed Carbon.	Ash.	Sulphur.	Second Geological Survey of Penna.
Cumberland	0.893	15.522	74.289	9.296	0.714	H[3] P. 101.
Broad Top	0.770	18.180	73.340	6.690	1.020	Kelly (D.)
Bennington	1.200	23.680	68.170	5.730	0.620	Miller (B.)
Johnstown	0.720	16.490	73.840	7.970	1 970	C. I. Co. Dr. F.
Blairsville	0.920	24.360	62.220	7.590	4.920	H. 4, Unwashed.
Connellsville	1.260	31.800	59.790	7.160	0.530	C. I. Co. Dr. F.
Greensburg	1.020	33.500	61.340	3.280	0.860	M. M., p. 23, 24.
Irwin	1.410	37.660	54 440	5.860	0.640	M. M., p. 22.
Armstrong Co	0.960	38.200	52.030	5.140	3.660	M[3], p. 56.

Whether this quality of coal will be found in the extensions of this strip, northeastward and southwestward parelleling the trend of the Appalachian mountain ranges, in other words, the ultimate effects of the heat diffused during the period of the flexing of the coal measures, in fixing the condition of the quality of the coal as regards leanness or richness in bituminous matters, is yet to be learned.

* Mr. Walter M. Stein, Metallurgical Engineer, No. 325 Walnut St., Phila., advises me that he has an experimental plant for this purpose.

As the dynamic force that flexed and folded the eastern side of the North American continent exerted its greatest force at the east, diminishing gradually westward, the evidence of the action of the diffused heat from these movements is seen in its effect in the hard dry anthracite coals of Pennsylvania and Rhode Island, the dry semi-bituminous coals of Broad Top and Cumberland, with the increase of bituminization of the coals westward, until the normal undisturbed condition is reached in the great central plain of the continent.

It has been made evident by past practical experience that in the Appalachian region coals containing 18 to 35 per cent. of volatile combustible matters can be made, with proper oven treatment, into good coke.

Northwestward, amongst the more recent deposits of coals, the ratio of volatile hydro-carbons to the fixed carbon does not indicate, with some exceptions, their coking properties, as some of these coals inheriting 35 to 45 per cent. of these matters fail to fuse in any type of coke oven.

It has been noted in the reports of the United States Geological Survey that a coal found in Alaska, and containing the following elements, *could not be coked :*

ALASKA COAL.

Moisture, 212° F	9.31
Volatile Combustible Matters	46.14
Fixed Carbon	40.85
Ash	3.70
	100

A shipment of coal from Sandcoulee, Cascade County, Montana, was tested at the coke works of the Cambria Iron Company in the Connellsville region, in 1889.

A general average of this coal from a bed 6 feet 6 inches to 8 feet 6 inches thick, showed the following composition:

Moisture at 212° F	2.26
Fixed Carbon	54.47
Volatile Combustible Matters	33.60
Ash	7.82
Sulphur	1.85
Phosphorus	0.009
	100.009

The two benches of this coal-bed differed in quality; the upper bench affords a dull dry coal, the lower bench is brighter and more fusible in the coke oven.

The coke was made from an average of both benches—it was analyzed as follows:

Fixed Carbon	88.35
Ash	10.85
Sulphur	1.79
Phosphorus	0.009
	100

This coke exhibited a composite structure. The coal from the upper bench did not fuse. The coking operation expelled the volatile matters, leaving the normal structure of the pieces of coal unchanged—it was simply *charred coal.*

This coal received preparatory treatment in various ways before it was charged into the ovens, it was broken into small pieces, wetted, etc. The operations of coking were also varied, from slow mild heat to quick intense heat. The latter method gave the better results. The coke was made in the Bee-Hive ovens with great care and by expert cokers.

The ultimate decision was, that whilst this *Cretaceous* coal is well adapted for generating steam and for domestic and other uses, yet it does not fuse in coking so as to produce a merchantable coke.

Another sample of coal, from the Belt Mountain, 14 miles south of Sandcoulee, Montana, was forwarded to Connellsville for test in coking. The coal bed has three benches, the average analysis of these is as follows:

BELT MOUNTAIN COAL.

Moisture, 212° F.	2.98
Volatile Combustible Matters	28.72
Fixed Carbon	53.31
Ash	13.34
Sulphur	1.65
Phosphorus	0.012
	100

This coal under repeated efforts in coking, came out of the oven *charred.* It could not be coked.

THE APPOLT COKE OVEN.

The Appolt coke oven, in its general plan, is a radical departure from its predecessors.

It was evidently designed to meet the general conditions covered by the Belgian oven, with additional elements in the economy of the work of coking, and in its adaptibility for coking dry coals, which require a rapid exposure to a high temperature, in the initial stage of coking, to utilize the small ratio of fusing matters in such coals.

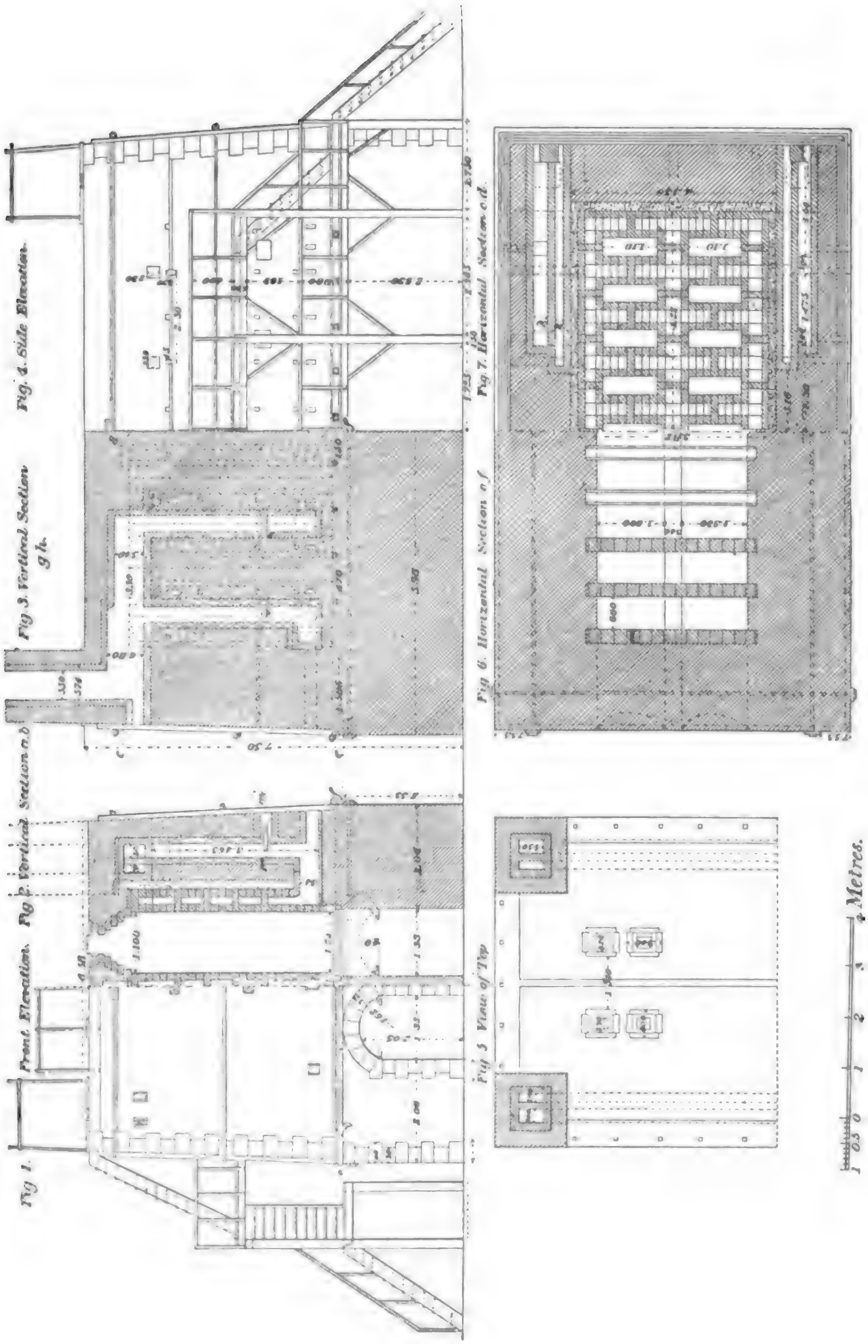


FIG. 48.--APPOLT'S COKE OVEN.--8 RETORTS.

This oven, Fig. 48, is described as "consisting essentially of a series of upright rectangular retorts, the longer sides of the rectangle being two or three times the length of the shorter. The retort is wider at the bottom

than at the top, to facilitate the discharge of the coke. These retorts are grouped in companies of 12, 18, or 24, as the requirements may be; the whole inclosed in a large rectangular brick chamber, which may be termed the combustion chamber, the retorts being surrounded on all sides by air spaces, these spaces being in communication, and the walls which form the sides of the retorts connected together by solid blocks of fire-brick.

"Between the fire-brick walls of the combustion chamber and anout side brick wall is a space filled loosely with some powdered substance, as sand or other poor conductor of heat, which allows a certain degree of expansion and contraction of the fire-brick wall of the combustion chamber within. This combustion chamber for a group of 12 retorts would be about 17 feet long, by 11 feet 6 inches wide, and 13 feet high.

"Each retort is about 4 feet long and 1 foot 6 inches wide at the base, and 3 feet 8 inches long and 13 inches wide at the upper part, the walls being about 4¾ inches thick.

"The ovens are placed in two rows, back to back, the bottoms being provided with cast-iron doors strengthened by transverse bars of wrought-iron. The partition walls of each chamber, at a distance of from 16 inches to 2 feet from the base, are traversed by two rows of of small horizontal openings 5½ inches long and about 3½ inches high, 9 on the wide side and 3 on the narrow side. At the upper part there are three similar openings on the wide side only.

"Through these openings the volatile products evolved during the coking of the coal pass into the surrounding open spaces of the combustion chamber, where they are burned by mixture with atmospheric air admitted through holes in the wide sides of the outer wall of the oven."*

The designs of these ovens are very complete, especially on the lines of rapid and economical work.

The yields of coke as given by the Messrs. Appolt are as follows:

Each retort contains about 1½ tons of coal. The coking is usually completed in 24 hours. Belgian coking coal gave from 80 to 82 per cent. of coke, and English coking coal 72 to 73 per cent. No analyses are given with these statements and we can learn little of the actual work of this oven.

Theoretically this is a very perfect oven, yet it has not come into as general use as some of its competitors.

The two chief elements in retarding its more general use consist: *First*, in its large original cost and in the expensive cost of repairs. *Second*, from the great height of the oven, 13 feet, compelling coking under much pressure and producing in the middle or lower sections of oven, coke of objectionable *dense physical structure*. This dense product of two-thirds of its coke must be injurious to its character, especially in blast-furnace use.

* From Report of J. D. Weeks, Esq., to Census Office, 1885.

It is probable that the adverse conclusion of Sir I. Lowthian Bell in 1871, regarding the value of Appolt and other flued oven cokes, was induced by the *dense* physical structure of these cokes, as it is difficult to understand how their chemical composition could invite criticism, for the reason that in the Bee-Hive and other open or non-flued ovens, some of the fixed carbon of the coal is consumed in coking, reducing its volume in the coke.

We have thus far considered the designs and work of these three primary types of coke ovens: The horizontal chambered Bee-Hive and its associated plans; the vertical chambered Belgian, Coppée and relatives, and the vertical columnar chambered oven, the Appolt, which appears to have no successor.

The positions of the coal in the chambers of these three typical coke ovens have been clearly defined by the three postures in which a common brick can be placed. Laying it horizontally on its *broadest side* shows the posture of the charge of coal in the Bee-Hive type of oven; placing the brick *vertically on its side* illustrates the shape in which the coal is coked in the Belgian type of ovens, and by placing the brick vertically on its *end*, the posture of the charge of coal in the Appolt oven is accurately represented.

It has been pointed out, that the designs of the coke ovens following the original Bee-Hive, were chiefly made to satisfy the three principal conditions of the manufacture of coke. *First.* To coke inferior coking coals. *Second.* To economize the work of coking, by mechanical appliances. *Third.* To secure a large percentage of coke from the coal charged into oven.

The relative ultimate economies of each system of coking will hereafter be considered in detail, embracing capital invested in construction of each type of oven plant, the percentage of coke obtained, cost of making it, and the quality and value of the coke produced.

With the expansion of the use of coke in metallurgical operations on the one side, and the gradual exhaustion of the areas of the best coking coals on the other, it becomes evident that to meet the coking requirements of the lower qualities of coking coals special plans of coke ovens will be required to assure the best possible product of coke.

MODIFICATIONS OF APPOLT COKE OVENS AT BLANZY.

We make the subjoined extracts from a communication to the Societe de l'Industrie Minerale, by M. Marle, engineer at the Blanzy collieries. Several types of ovens have been employed at Blanzy, where from 20,000 to 25,000 tons of coke are made each year, but of these different types only two remain—the horizontal Coppée and the Appolt type.

" A few modifications have been introduced in the Appolt ovens, in order to utilize the waste heat for firing the boilers, or to take off the gas for

other purposes. The Appolt oven generally consists of 18 vertical retorts, arranged in two rows in a large heating chamber. The gases issuing from the retorts by narrow horizontal apertures at the bottom are ignited and permeate through the heating chamber, air entering by orifices at different levels. The products of combustion escape through eight passages at the level of the lower part of the retorts, communicating by horizontal flues with vertical chimneys at the four corners of the oven. Eight other and smaller orifices at the top of the heating chamber may also serve to take off the waste flames; but they are not generally employed, as their use leads to a cooling down of the lower part of the oven. The outlet passages, below the level of the gas exits, must draw along a portion of these gases before their complete combustion, and without their having contributed to heating the oven; so that, in the chimneys, and especially where the passage is throttled by dampers, the temperature is very high, rendering maintenance costly and difficult. Moreover, this arrangement gives but little facility for graduating the temperatures, which are always too high in the middle of the oven, and too low at the two ends, thus delaying the operation of coking in the retorts at the corners, which cannot be drawn every 24 hours.

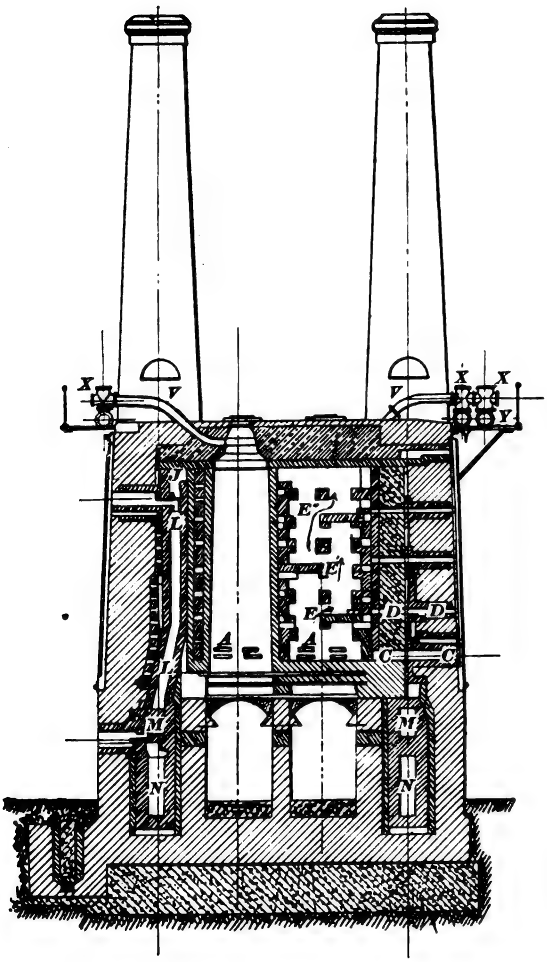


FIG. 49.—MODIFICATIONS OF APPOLT COKE OVENS AT BLANZY.

"In order to improve this state of things the direction of the gases has been completely changed. They leave the retorts by narrow apertures, *A A*, (see Fig. 49) at the bottom, and air for combustion enters by the passages *C C* and *D D*, at different levels as before; but the products of combustion are entirely evacuated at the upper portion of the heat-

ing chamber, and the gases, before arriving there, are obliged to follow a course, $E\,E'E''$, which forces the gas and air to mingle and enter into combustion, thus heating, as evenly as possible all the parts of the oven, while apertures with dampers are provided in the partitions for still better regulating the temperature.

"In the long sides of the oven there are as many evacuation apertures, J, as there are retorts; and, besides, at each end there are four apertures in the shorter sides, so as to heat the corner compartments which, since this modification, coke as rapidly as the others. Each of these apertures is fitted with a damper X, which permits of regulating at will the temperature of coking; and they communicate with a descending chimney $L\,L'$, traversing the whole height of the oven, and then enter the horizontal collector $M\,M$, divided in the middle by a vertical partition, into two equal parts.

"Owing to this arrangement the heating chamber is itself surrounded by all these chimneys $L\,L'$, which heat it still further, and protect it from external cooling, while the chimneys themselves are separated from the outer masonry by an air space which also protects them. From the collector $M\,M$, the gases pass into another flue $N\,N$, by means of four apertures fitted with dampers, and, when they reach this flue, the gases may be sent, at will, under the boilers and thence up their chimneys, or directly, on the other side, up other chimneys, dampers serving to direct the gases to one or other end, according to requirements.

"This double direction was rendered necessary by the intermittent working of the boilers, which are only in use by day, while it also permits of a complete stoppage, so far as the boilers are concerned, for cleaning and repairing them. The object of the collector $M\,M$, is to regulate the draught in the descending chimneys LL', which, without such an arrangement, would always have too strong a draught on the side where the gases were directed. Lastly, the oven may be completely closed by the dampers on Sundays and holidays, when the ovens are not drawn.

"The flues, $M\,M$ and $N\,N$, and descending chimneys $L\,L'$, are for a considerable distance surrounded by air, which is raised to a tolerably high temperature; and this heated air may, if required, be used for the combustion of the gases in the heating chamber by suitably regulating the dampers U. It was, however, necessary to discontinue the use of this hot air until the excess of gas produced by the oven was taken off, as the temperature which it produced was too high and might damage the bricks of the oven.

"The boilers are vertical, and provided below with a series of Mac-Nicol tubes, which greatly increases their evaporating power. They supply steam for driving the lifts, the coke breakers, and a washing apparatus. On Mondays, when there is no gas in the ovens, it becomes necessary to heat them, so as to have steam enough to begin work; and for this purpose they are provided with grates, so that they may be fired like ordinary boilers.

"The first two Appolt furnaces constructed by the Blanzy Company in 1862 were built, as usual, of burnt bricks, which it was necessary to cut and square carefully; but, noticing the difficulty caused and length of time required by this work, the late M. Jules Chagot, who then managed the Blanzy Colliery, conceived the idea of building the ovens with unburnt bricks, as practised in the furnaces of glass works. Accordingly, since 1866, all the ovens have been constructed in this manner, except one, in which case there was no time to wait for the bricks. One consequence of the use of unburnt bricks is that they must be made on the spot, as they cannot be transported easily.

"This system possesses the following advantages: (1.) Facility for squaring the bricks, which is done with a scraper instead of by hammer and chisel, thus economizing about one-sixth of the labor. (2.) The faculty of the unburnt bricks to adhere together, so as to make of each retort a monolith, the joints of which cannot be detected. (3.) Saving of the burning, which is effected when firing up the oven, which must always be heated very slowly, whatever be the method of construction.

"In addition to the above, the manufacture of the bricks on the spot has the advantage of leaving no doubt as to their quality and composition, or the manner in which they may be expected to behave in the fire, and it also permits of varying the composition according to the position occupied by an individual brick, of using very large bricks and of thus diminishing the number required. In the ovens built at Blanzy, the bricks are at least 25 cm. (10 inches) high; each course of a compartment is built of six bricks; four courses of the upper portion are made each in a single piece, and each course of the descending chimneys, also in a single piece, so that it may be laid very rapidly. In cases where the bricks are not required to adhere, in order to prevent displacement, a piece of wood or cardboard is introduced into the joint during construction and this packing piece is consumed when firing up. Actual experiment has shown the amount of clearance that must be left, which is greater in proportion to the quantity of quartz entering into the composition of the brick.

"Before charging the oven it must be fired up with great precaution for at least three weeks; and it is necessary to keep a watch on the expansion, and unscrew the nuts of the tie-rods as required. All the nuts must be provided with lead washers, the squeezing out of which gives warning of the moment when they must be slacked. Thanks to all these precautions, it was found possible to construct the last oven with 22 compartments instead of 18, without the slightest fracture being perceptible in the retort. There is an advantage in getting as many compartments as possible in the same bank, because the cost of the two heads, of the chimneys and of the boilers is spread over a larger number of retorts, and therefore over a greater production of coke.

"On noticing what happens in the retorts after charging, it will be seen that, during the greater portion of the carbonization, the gas attains considerable pressure inside, and has a tendency to escape, not only by the narrow aperatures intended for this purpose at the bottom of the retort, but also at the upper and lower joints if they are not made well. If, therefore, during this period, the gas be put in communication with a gasometer, the pressure of which is regulated very low, the gasometer will be filled without air entering the retort. As, in the present instance, the gasometer of the gasworks is 250 m. (273 yards) from the oven, an exhauster will be added for drawing off the gas from the retort, while leaving behind it sufficient pressure to prevent the possibility of a vacuum being formed in the retort. It will be possible, with practice, to determine the time during which communication must be maintained, and at the end of this period a valve must be closed, allowing the gas to escape by the apertures *A A*, (in the accompanying cross-section of the new oven, Fig. 49) for taking off the gases. The gas will be taken off by the pipes *V V*, the valves *X X*, and the general pipes *Y Y*, in communication with the exhauster. If, later on, it be found advisable to take off all the gas for recovering the tar and the ammoniacal liquor, the apertures *A A*, will be closed; and a second valve *X'*, and pipe, *Y'*, will be added for collecting the gas not intended for lighting. After their tar and ammoniacal liquor is condensed, they will be sent into the flues *C D*, where they will burn with the hot air, serving to maintain the heat of the ovens. The flues *C* and *D*, are, in fact, already arranged for receiving the gas pipes.

"With Appolt ovens, more labor is required than in any others. For 17 or 18 hectolitres (mean 62 cubic feet) of coal charged, two hectolitres (7 cubic feet) of coke-dust must be charged in, for closing the apertures at top and bottom, and also at least half that quantity of small coke, for protecting the gas exits *A A*, and preventing them from being obstructed by the coal. When the coke is drawn, this dust and small coke must again be withdrawn from the batch, which is a double work, increasing the volumes to be handled by 3-18ths on charging, and the same on drawing, making $\frac{1}{3}$ together. Hitherto the drawn coke, received in a tram, has been quenched and tipped on a floor, where the separation, screening and loading up were effected by hand.

"To lessen these expenses, the company put up a mechanical screen. Trams of the drawn and quenched coke are brought by an endless chain in front of a pit into which the coke is tipped, and then raised by a Jacob's ladder to the top of the shed whence it falls onto a screen, with bars 5 cm. (2 inches) apart, which keeps back the large coke. The latter falls into a hopper, where it is stored, and whence it may be charged directly into wagons running on rails by a sliding door at the bottom, the overplus being directed into a *trommel* or revolving drum, which divides it into four sizes, from dust to 40 mm. (1 9-16 inches).

"As the quantities of small coke produced are not sufficient for the demand, part of the large coke, instead of falling into the loading hopper, will be sent to a breaker and divided by a similar *trommel* into the same classes as those referred to above. It is expected that this arrangement will permit of reducing by more than half the labor required. The dust and the small coke required for charging into the retorts with the coal will be led to hoppers at the side of the ovens, whence they will be taken by the charging trams.

"The coal used for coking is of the long-flame bituminous variety containing: Carbon, 77.82 per cent.; hydrogen, 5.2; oxygen, 9.17, and nitrogen, 1.31, with an average of 6.5 per cent. of ash, yielding in the crucible a mean of 63.71 per cent. of coke, which is adhesive and rather soft, its structure showing long, bright needles.

"For some usages a harder coke is made from a mixture of bituminous and anthracitous coal The latter, obtained from the west of the concession, contains: Carbon, 82.48 per cent.; hydrogen, 3.88; oxygen and nitrogen, 6.14, with a mean content of 7.5 per cent. of ash, yielding in the crucible 83.5 per cent. of pulverulent coke, but the mixture of this coal with the bituminous produces a large and dense coke, in which the above named needles are absent."

It is quite probable that this type of a coke oven will be found to be well adapted for the successful coking of the western coals, rich in bituminous matter. The dimensions of the coking chambers will require enlargement for the best results from these coals.—Ed.

SIMON-CARVÉS OVEN.

About the middle of the eighteenth century, efforts were made in France and England for extracting the by-products of tar and ammonia from the gases evolved in coking coal.

This was stimulated at this time, by the increasing use of coke in the presence of a declining supply of charcoal.

These efforts were made prior to the practical introduction of works for making illuminating gas from coal.

It is on record that Bolton and Watts first erected private gas works in 1798; this was followed by the construction of public gas works in London in 1813, Paris in 1815, and in Berlin in 1826.

The by-products of tar and ammonia, at these early gas works, were regarded as very undesirable resultants, which required removal in purifying the illuminating gas, as at this time no useful place appeared for them in the industrial arts.

A limited application was provided for the use of tar in Germany in 1846, in the manufacture of roofing felt.

In England tar was used in a small way in 1838, for the preservation of timbers.

This was followed by the utilization of the sulphate of ammonia as a fertilizer, thus affording additional revenue to the gas makers and coke manufacturers.

A long interval of slow progress followed the early production of these by-products in the coke making industry. This arose in part from the feeling entertained at this period, that ovens making by-products could only produce an inferior quality of coke. Doubtless this judgment was induced from the poor quality of gas-house coke for metallurgical purposes, and that coke for blast furnace use could only be made in Bee-Hive or similar types of coke ovens, untrammelled by the cumbersome apparatus for saving these by-products.

The foundation of ultimate success, in making a good quality of coke and at the same time securing the by-products, was laid in France by Knab's retort coke oven in 1856; but the condensation of tar and ammonia from the gases from these ovens, was only practically successful by Haupart and Carvés oven about the year 1881.

This success imparted to the saving of by-products renewed interest and gave the coke making industry additional value in France, Germany and England.

The most important improvement in the Carvés oven, from the Knab, consists in the addition of side flues. The Knab oven had only bottom flues.

Mr. H. Simon, in England, improved the Carvés oven very materially by adding recuperating flues in front of the ovens. This recuperator affords ample heat in the process of coking and overcomes the necessity of using a portion of the fixed carbon of the coal for supplemental heat in coking.

The Simon-Carvés retort coke oven is a closed oven, with horizontal flues and apparatus for saving by-products.

Its introduction was followed by a large number of retort coke ovens with and and without appliances for securing by-products.

It would exceed the limits of this volume, at this time, to follow up in order the several types of ovens, from the ancient Bee-Hive to the modern retort oven, but it is designed to submit the chief successful and practical types of these ovens, with their individual desirable elements.

It may be noted here, that in the progress of development of the by-product industry, three special root types of ovens have been used.

The first, the Bee-Hive, into which air is moderately admitted and its heat maintained by burning a portion of the fixed carbon of the coal. Its by-products were moderate in quantity as well as in value. Aitken of Scotland, and Jamison of England have successfully applied to this type of coke ovens appliances for the saving of by-products of tar and ammonia.

The second, the Coppée, an improvement on the Knab, is a closed or retort oven, with vertical flues.

The third, the Simon-Carvés oven is a closed retort oven with horizontal flues and recuperator.

These two types of closed ovens utilize the oven gases, after having been deprived of by-products, by returning them to heat the chambers of the ovens, thus saving the burning of the fixed carbon of the coal in coking.

This utilization of the gases evolved in coking, by returning them to supplement the oven heat, is the distinctive characteristic of the family of retort coke ovens.

The Simon-Carvés coke ovens, Fig. 50, are constructed to produce coke, suitable for all industrial purposes, with an economy of coal, and at the same time to collect all the by-products in the distillation of coal.

These by-products serve for the manufacture of ammonia and ammonia compounds, tar and all its derivatives, benzol, carbolic acid, anthracene, coloring matter, etc.

In the Simon-Carvés oven the carbonization takes place in a closed retort. There is neither introduction of air nor combustion in the interior of the oven. To convert the coal into coke the heat is applied externally through flues passing under the floor and along the sides of the ovens. The heat is generated from the gases obtained in the ovens from the coal, but only after these gases have been deprived of every particle utilizable as a by-product.

Hot air is employed to render the combustion more effective, waste heat from the ovens being utilized to heat the air. The accompanying drawings will illustrate the main operations of this oven.

The coal to be coked is conveyed to the top of the ovens by the coal larry L, L^1; by opening the doors of these larries, the coal falls into the oven through the ports O, O. These openings and the doors P^1, P^2, at each end of oven are then tightly closed and luted, so as to prevent the admission of air. The valve V is then opened, putting the interior of the ovens in communication with the exhauster pipe P.

This conveys the gases evolved from the coking coal to the condensers and scrubbers, where they are deprived of the by-products and returned to be burned with hot air in the oven flues.

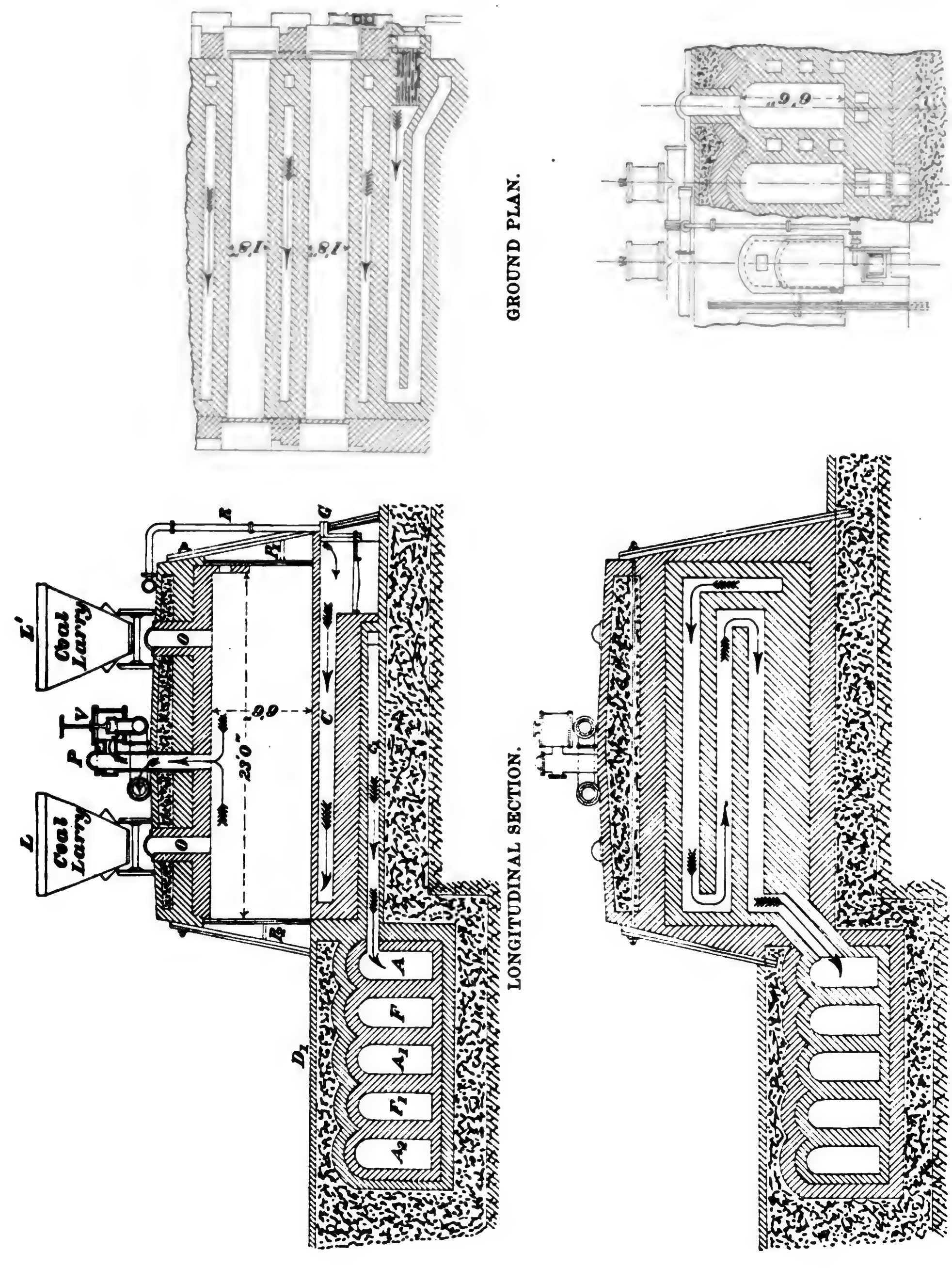
When the carbonization is completed, the doors of the ovens are opened and the coke pushed on the platform or wharf D, by a steam ram. The cooling of the coke is done on this wharf.

The interior dimensions of this oven are as follows: Length, 23 feet; width, 18 to 20 inches; height, 6 feet 6 inches.

The *Recuperator* is an important and later element in this oven, it is described as follows: Externally to the brickwork of the ovens are provided five longitudinal flues A, F, A_1, F_1, A_2; two of these flues, F and F_1, allow the gaseous products of combustion to escape to the chimney, the order three flues, contiguous to the former ones, serve as passages for the air, which is heated on its way by contact with the walls of the flues F and F_1.

The flues F and F_1 communicate respectively with the chimney and the

Description :—L, L', Charging Larries; O, O, Charging Ports to Ovens; P_1, P_2, Doors to each end of Ovens; R, Pipe and Tuyeres for Transmitting Gases; C, Flues under Ovens for Gases and Heated Air; G, Nozzle to mix Gases with Air in Flues C; A, F, A_1, F_1, A_2, Recuperator for Smoke and Waste Heat from Flues C; F, F_1, Flues to allow the Gaseous Products to escape to Chimney; A, A_1, A_2, Flues for passage of Air which is heated on its way by contact with the hot walls of the Flues F, F_1; P, Opening on top of Oven to collect the Gases; V, Valve to Regulate the Gases; D_1, Coke Wharf where the coke is cooled.



SECTION SHOWING FLUES BETWEEN OVENS.

FIG. 59. – THE SIMON-CARVÉS COKE OVEN.

steam boilers which can be placed at each end of the row of ovens, to utilize further the waste heat of the products of combustion.

The charge of coal for each oven is 5½ net tons. The coking requires about 48 hours with the usual quality of coals. With coal affording 75 per cent. of coke, the production of an oven is 2.1 to 2.2 tons of coke per day, and about 10 per cent. of ammoniacal water and 3 per cent. of tar.

A battery of 50 ovens at Bearspark Colliery, England, makes about 900 net tons of coke per week from coal constituted as follows:

Moisture	0.84
Volatile Matters	26.85
Fixed Carbon	68.44
Ash	3.10
Sulphur	0.77
	100.00

The theoretic coke from the above coal is 72 per cent. The charge into the oven is 5½ net tons of coal, yielding about $4\frac{2}{10}$ tons of coke in 48 hours.

Deducting for ashes and breeze, the product of marketable coke is practically 75 per cent. This shows a small accretion from the deposit of carbon in the process of coking—4%.

The cost of labor in coking and collecting by-products is estimated at 48 cents per net ton of coke made in a battery of 50 ovens, producing together 105 tons of coke, per 24 hours.

The annual product of 50 ovens of marketable coke would be about 34,000 net tons.

The value of the by-products of tar and ammonia is estimated at 68 cents per net ton of coke made.

The cost of a plant of 50 Simon-Carvés ovens, with appliances for saving the by-products in the United States, would be about as follows—depending somewhat on locality.

50 Ovens at $1,300 each	$65,000.00
By-products, appliances, tracks, houses, elevators, etc., etc	50,000.00
Total	$115,000.00

This estimate does not embrace a coal washing plant. If such is required an additional sum would be added to the above, depending on the character of the coal and the impurities to be removed.

With coals inheriting 26 per cent. of volatile matters, the saving of by-products becomes more assured, but with the large expense of the apparatus for saving by-products in the original cost of the coking plant, and in its continuous and expensive operation and maintenance, it becomes a matter demanding careful investigation, whether at this time it is an

auxiliary that will surely afford to the coke manufacturer an income that will compensate for investments in this addition to piant, and afford a return to cover the additional labor and repairs of apparatus.

A thorough test of the coal, for its value in affording by-products, should be made as a prime element in the investigation of this matter.*

These Simon-Carvés ovens can be used in the manufacture of coke, with or without appliances for the saving of the by-products of tar and ammonia.

Its system of horizontal flues is commended for efficiency and economy of repairs.

G. SEIBEL'S RETORT COKE OVEN.

BY-PRODUCT OVEN.

The *Seibel* retort coke oven was patented by its inventor, Georges Seibel, in France in 1881, in England in 1882 and in the United States of America in 1883.

Two main principles appear to have been kept in view by Mr. Seibel in the planning of this oven. First—to preserve the mode of carbonization which secures a maximum deposit of carbon from the hydro-carbon gases in their ascent through the upper incandescent coking portion of the charge, and second—to arrange tuyers and horizontal flues for the utmost economy in maintaining oven heat by combustion of the returned gases, deprived of the by-products, without the use of grates or complicated regenerators.

The details of this oven are all in harmony with the above governing principles, exhibiting practical skill in the design of the retort coke oven and its by-product saving appliances.

Through the courtesy of Mr. W. M. Stein of Philadelphia, I am enabled to submit the consideration that guided Mr. Seibel, the inventor, in designing this oven, from his own notes, with description of the oven and its mode of operation.

"Until recent years, the method of coking in hermetically closed ovens, permitting the saving of tar and ammonia, was not considered a good one by the best engineers.

"It was generally believed that, at best, only coke of inferior quality could be obtained, hardly comparable with that of gas works.

"For a long time, the coke ovens of the works of Marais near St. Etienne, Loire, modified according to the system Knab, failed to find imitation. Today this method of carbonization with saving of by-products is more appreciated, its advantages recognized and the prejudice entertained against the process is given up, especially in Europe.

* Mr. Walter M. Stein, Metallurgical Engineer, No. 325 Walnut St. Philadelphia, can make these tests.

"Experience has demonstrated that the coke thus obtained is not inferior in quality to that obtained from the same coal in ovens of the other systems. Germany has adopted ovens heated with regenerated gas, for saving of tar and manufacturing sulphate of ammonia.

"The engineers to-day study and apply the different systems. Belgium has ovens heated with gas and arranged to gather tar and aqua ammonia, producing at the same time perfect coke, suitable for all metallurgical purposes.

"In France, on the contrary, this question seems to have remained indifferent to the interested parties.

"One large iron company only, the company of Terrenoir Savoutte and Besseges had adopted the ovens of the system Carvés and Co., in 1867. In three intervals, in 1867, 1873, and 1875, this company has built at Besseges, 85 ovens of this type, being perfectly satisfied with the results. A group of these ovens is also in operation for the past few years at Terrenoir.

"Such is the condition of carbonization with saving of by-products in the principal coal centers of Europe.

"It may be said, however, that, though this question met with little interest in France, it is beyond dispute that the improvement originated in this country.

"In this direction the company of the mines of Campagnac located at Crausac, Aveyron, has been quite successful, effecting a remarkable improvement in the coking industry.

"In 1878–1879 this company built a first battery of 9 ovens, modifying the previously adopted method of carbonization. The result obtained surpassed all expectation.

"In 1882 the company added 10 ovens to its first battery, which have given the same satisfaction as the first. The mere enumeration of these results will be amply sufficient to emphasize the progress accomplished.

"The coal of the company of the mines of Campagnac gives theoretically an average yield of 64 per cent. of coke, ashes included, and 36 per cent. of volatile matters. The actual yield of these ovens (Seibel) proved to be 75 per cent.

"The results obtained during the whole year 1883 were, as above noted, 75 per cent., that is, 11 per cent. in excess of the theoretical yield.

"The production of tar was 54 pounds per each gross ton of coal charged. From these results the following figures exhibit the working of these ovens during the year 1883.

Coal charged into ovens	14,675 gross tons
Production of coke	11,006¼ gross tons
Saving of Tar	360¾ gross tons

"The company of Campagnac commenced to save the aqua ammonia and manufacture sulphate of ammonia only after the beginning of the year 1883. The yield of sulphate of ammonia is 11 pounds for each gross ton

of coal charged. The company then increased the surface of the condensing apparatus of the gases. The tar production showed the effect immediately, increasing to 66 pounds for each gross ton of coal charged.

"It follows from these figures that a coke oven of this system, using this or a similar quality of coal, will produce yearly as follows:

648.81 net tons of coke.
25.99 net tons of tar.
4.325 net tons of sulphate of ammonia.

"These results require no comment, I shall therefore not dwell upon them, but complete the information by adding, that the coke made from this coal is superior in quality to that obtained from similar coal in either the Appolt or Coppée ovens.

"We have during several months made coke regularly with our coal in those two types of ovens and ours, and could therefore determine the difference in the products which was very easily perceptible.

"The coke obtained from our ovens is harder and denser than that obtained in the ovens named above. This improvement is the consequence of the increase of yield, which surpasses the theoretical yield by 11 per cent.

"This increase is obtained at the expense of the carbon of the hydro-carbons of the gases, which dissociating, deposit part of their carbon in the pores of the coke. In short, there is, during the period of distillation, a dissociation of the gases, whereby a part of their carbon, being now in elementary form, unites itself with the coke or fixed carbon, enriching it and increasing its quantity and quality.

"Before describing the ovens, I will sum up the reasons which have been guiding me in their construction.

"It has been proven long ago, that the hydrocarbon gases produced by the distillation of the coal, give up under certain favorable conditions a larger or smaller proportion of their combined carbon. The formation of graphite in the retorts of gas works is due to this cause. On the other hand if one compares carefully the coke produced in a Bee-Hive oven, with the coke from the same coal produced in ovens of the other types, it will be recognized that the coke from the Bee-Hive ovens is denser, harder and in thicker pieces, than that produced by ovens of other systems. The difference is especially marked in coke from coals rich in volatile matter, like those of the basin Decazeville and Aubin.

"This difference in quality was formerly so well known in the basin of Decazeville that the foundry owners would take only Bee-Hive coke for smelting in cupolas, excluding coke from the ovens Semet, Appolt and Coppée, which was formerly used simultaneously with Bee-Hive coke in these works.

"The difference in quality can only be due to the manner of carbonization. In the Bee-Hive ovens formerly used, the process of coking commences

at the top and then goes downward. Now if a charge of coal is put in a heated Bee-Hive oven, all parts of the oven with which the coal comes in contact, walls and bottom, cool immediately, the dome only retaining its heat. The latter radiates heat over the charge and starts the distillation there. This distillation continues downward in the mass of coal and the gases produced in the lower portions are forced to traverse a porous mass during the formation of coke, in order to escape through the only opening in the roof. The hydrocarbon gases traversing in the early stage of the coking process through a spongy mass are consequently surrounded by conditions very favorable to their dissociation, and give up to the upper regions of the charge a certain proportion of their carbon. This fact can be proven by a careful examination of a coke needle.

"These needles are formed vertically in the Bee-Hive ovens; at the lower part of the needle, where it touches the bottom of the oven, the grain of the coke is porous, puffed up, coarse; while it gradually becomes finer and denser, approaching the top of the needle. The only possible explanation of this difference in the condition of the same needle is the one given above; it gives therefore a valuable hint as to the dimensions and particular arrangement which must be observed in designing the oven. In spite of the quality of the coke produced in the Bee-Hive ovens in the basin of Decazeville and Aubin, they have been abandoned. They yielded too small a quantity of coke.

"Assisted by the observations just related, and information gained in the position of Managing Engineer at the mines of Decazeville, I had, when called upon to construct coke ovens for the Company of the Mines of Campagnac, already studied up a type of oven reproducing the method of carbonization in use in the Bee-Hive oven, that is, where carbonization commences at the top and extends downward, but avoiding the losses which are incurred by combustion of the fixed carbon.

"The retort coke ovens, of the company of the mines of Campagnac, carbonize from the top downward and are hermetically sealed.

"The following very simple arrangement was adopted. As mentioned above, the company of the Mines of Campagnac possesses a group of 19 ovens constructed in two batteries.

"The first experimental battery of 9 ovens and in addition to these 10 others have been built, the south end of the first battery being the north end of the second. Each retort oven is a long narrow arched chamber, 19 feet $8\frac{1}{4}$ inches long, 6 feet $6\frac{3}{4}$ inches high and $27\frac{1}{2}$ inches wide between the side walls.

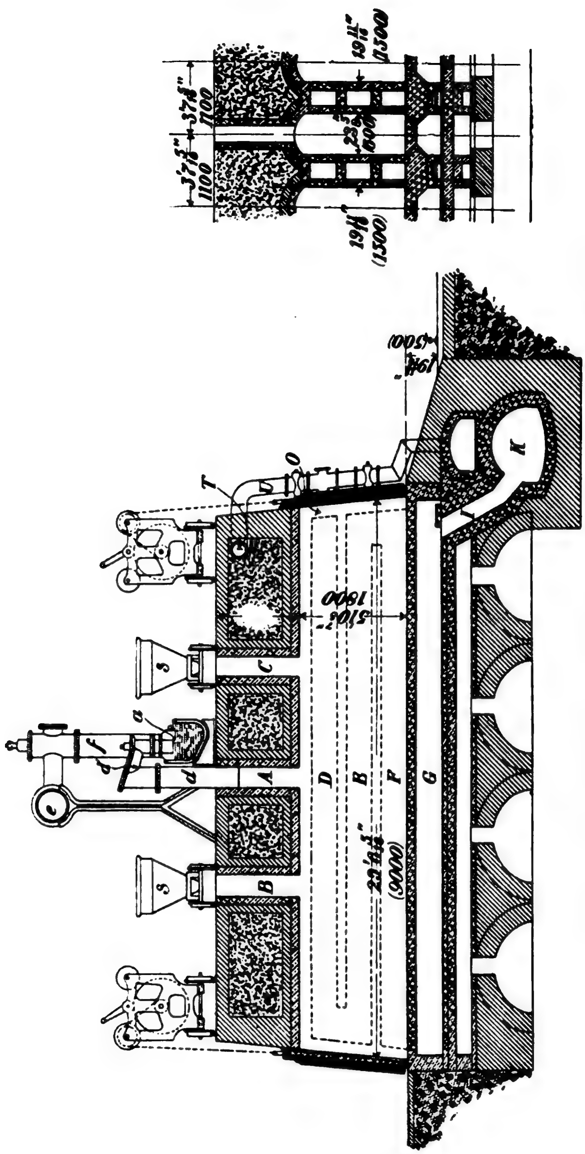


FIG. 51.--SEIBEL'S RETORT COKE OVENS WITH SAVING OF BY-PRODUCTS.

" See dimensions of a more modern oven, Fig. 51.

" The walls separating each oven from its neighboring one are 15¾ inches thick and are built of first class fire brick.

" The walls between the ovens contain three horizontal flues, connected with each other at their ends, so as to form a continuous flue as indicated by *D*, *E*, *F*, which is continued in *G*, under the sole of the oven, and finally leads through the flue *I*, into the main gas flue *K*. The latter takes the gases to the chimneys, built at the ends of the battery of ovens.

"The upper flue *D* has an opening at *O*, going through the wall to the outside of the oven in which the gas burner is placed and which will be described further on.

"In the middle of the retort of each oven, there is in the arch an opening *A* which allows the gases of distillation to escape.

"To the right and left are placed symmetrically the two other openings *B* and *C* for charging the coal.

"The ovens are closed at their ends by cast iron doors. Two swinging doors are placed over these. The doors as well as the charging ports are hermetically sealed by a clay point. Above the opening *A*, which allows the gases of distillation to escape, a vertical cast iron pipe *a*, is placed, which by a branch *d'*, connects with a small barrel *b*, the opening of which can be closed by a valve *a*. It is only necessary to lift the latter by its handle to effect the stoppage.

"The gases of the distillation escape by means of the pipes *d* and *d'* into the hydraulic main, common to each battery.

"The hydraulic main is connected with a collecting pipe *e*, by a vertical pipe *f*, which is also provided with a valve.

"Each battery has its hydraulic main connected with the collecting pipe *e*, which leads the gases of all the ovens to the condensing apparatus. An exhauster worked by steam, which absorbs these gases, forces them to traverse the various apparatus with gradually decreasing pressure. The gas gives up its tar and ammoniacal water, and is then returned to heat the ovens.

"The purified gas is driven back by the exhauster to the pipe *T*, which extends along the top of the ovens. From this pipe the gases are distributed equally to the tuyers by secondary pipes *U*, which take to the burners the quantity of gas necessary for each. The pipes *U* are supplied with valves which regulate or stop the flow of gas to the burners. These burners consist of two tubes, one within the other, and closed at the outer end by a flange. The inner one is a little smaller than the outer one, so as to have a circular space of 0.039 inch. Thus joined with the flanges put together, and the outer tube connected with the feeding pipe by a special small tube, it will be seen that the arriving gas flows in the upper part of the circular aperture between the tubes in form of an elongated crown. The air necessary for this crown of gas reaches the circular aperture by means of openings in the inner tube.

"The supply of air can be regulated by shutting these openings more or less.

"These are the general arrangements of the oven, it will now be easy to understand its operation.

"When an oven is charged and cut off from the battery by closing the valve *a*, in the small barrel *b*; it is then recharged with coal through the openings *B*, *C*, by means of the larries *S*, *S*. The charge of coal is piled up as high as possible in the oven, nearly to the spring of the arch, and is then

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levelled from both sides through the upper opening of the doors, which remain open while the coal is charged. This being done the charging ports *B*, *C*, are closed by lids, and the upper openings of the doors shut, both being hermetically sealed with clay.

"At the same time the valve *a* of the barrel *b*, is opened and the communication of the oven with the hydraulic main restored. The carbonization now proceeds regularly, the gases of distillation escaping under a small pressure through the opening *A*, and by means of the pipe *d*, *d'*, to the hydraulic main, from whence they go to the condensing apparatus.

"The coal charged being wet, the walls and floor of the oven in contact with it are considerably cooled. The arch is the only part of the oven remaining hot.

"On the other hand the two burners have continued heating the wall flues *D*, which in their function as combustion chambers of the gases, have a higher temperature than the flues *E*, *F*. It is, therefore, easily understood that the upper part of the charge will receive from the flues *D*, as well as from the hot arches by radiation, the greatest amount of heat.

"The distillation begins therefore very actively at the top of the charge and progresses downward. It will be seen from this that the carbonization begins at the top and goes downward, exactly as in the Bee-Hive ovens. The gases generated in the lower part of the charge, must, in order to escape through the only opening *A*, in the oven, traverse the upper regions which are ready settled and have been brought to a high temperature.

"This sifting of the gases causes them to give up part of their combined carbon, which settles in the pores of the coke already formed and in the fissures between the coke needles.

"I have endeavored to give the ovens such dimensions as are most likely to facilitate the dissociation of the hydrocarbon gases, which is such an essential part in the method of carbonization, just described.

"The general arrangement of the condensing apparatus, at the Mines, of Campagnac, is shown in Fig 2, which gives at the same time their connection with the coke ovens.

"At each end of the oven batteries, a boiler is heated with the products of combustion resulting from the heating gases, which must pass under the boiler on their way to the chimney. These boilers work alternately, just as one or the other chimney takes the products of combustion. Should it, however, be found necessary, both boilers and chimneys can be used.

"The by-product saving apparatus are as follows:—Fig. 52.

No. 1, Expansion regulating tank.
No. 2, Condenser.
No. 3, Pipe Condenser.
No. 4, 5, Scrubbers.
No. 6, Tar Condenser.
No. 7, Exhauster.

These apparatus work in the manner explained below.

1. Expansion regulating tank.

"This is a simple cylinder of sheet iron, 4 feet 3 inches in diameter and 16 feet 5 inches high, standing vertically. The gases of distillation arrive at the upper part, through the collecting pipe *e*, and leave the cylinder at the lower part. Arriving at this large tank, from the tube *e*, the gas expands, and this is sufficient to cause it to abandon a certain proportion of tar and ammoniacal water. The temperature of the gas in this reservoir varies with the external temperature and the amount of gas produced by the ovens; it is between 70° and 90° Celsius. The pressure on the contrary remains constant and is 0.

2. Square condenser.

"From the expansion tank the gas goes to a rectangular tank, 6½ feet high, 3 feet 4 inches wide and 3 feet deep. This tank is placed in another open at the top, of 1 foot height, 4 feet wide and 3 feet 7 inches deep, filled with water to the height of an overflow, which permits the discharge of the condensed liquids.

"The first tank is divided into six compartments by vertical hollow partitions, in which cold water circulates. These partitions are so arranged that the gas in order to circulate must pass from one compartment to the other, and bubble through the condensation water.

"Traversing this apparatus the temperature of the gases falls about 11° to 13° Celsius and they lose a considerable quantity of tar and ammoniacal water; the cooling surface of the tank being 258 square feet. Leaving the apparatus the gases have attained a depression of 0.08 to 0.18 meters of water.

3. Pipe condenser.

"From the square condenser the gas passes through a series of wrought iron serpentine pipes, water cooled from the top by a water spray. The condensing surface of these pipes is 1115 square feet, the decrease of temperature 20° to 26° Celsius.

4, 5. Scrubbers.

"Two scrubbers follow the pipe condensers; they are cylinders of 3 feet 4 inches diameter and 16 feet 5 inches in height and contain a series of plates so arranged that the gas entering these cylinders at the bottom, meets the water coming from the top and is methodically washed. The cylinders are filled over ⅔ of their height with crushed coke. In one of the scrubbers the gases are washed with ammoniacal waters in order to enrich the latter, in the other with pure water in order to extract as much ammonia as possible. After the first washing the depression of the gases is 0.15 to 0.22 meter of water, after the second washing 0.20 to 0.27 meter.

"The first washing lowers the temperature 10° to 15° Celsius, the second 5° to 6° Celsius.

6. Tar Condenser.

"This apparatus is built according to the principle of Pelouse and Andoin, and is used in large gas works to deprive the gases of the last particle of tar which they may yet hold.

"It consists of a series of metallic curtains, arranged vertically, one behind the other. These curtains are constructed of pieces of wire about $\frac{3}{4}$ inch in diameter, placed vertically, in frames, $\frac{3}{4}$ inch apart. Each curtain is placed behind the other in such a manner that the wire strings of one correspond to the space between the wires of the other.

"The gas, passing these obstacles, is subjected to a succession of shocks which cause it to yield up the last particle of tar it contains. To work properly, the needed depression of this apparatus must be 0.04 to 0.05 meter of water. This is regulated by augmenting or decreasing the passage surface of the gases. The frame bearing the series of metallic curtains is enclosed in a case on three sides. On the fourth side, the bottom, the seal is effected by the waters of condensation and the tar. By raising and lowering this frame in the waters, which have a constant level, the passage surface of the gases is increased or diminished and correspondingly the depression of the gases is increased or decreased.

7. The Exhauster.

"This exhauster is of Bourdon's system, exhausting the gases by means of a jet of steam.

"The force of the same can be regulated by the introduction of a needle in a conical opening. The exhauster is set so that there is neither pressure nor depression in the expansive tank, the first of the condensing apparatus.

"In this way a slight pressure of gas is maintained in the ovens, excluding the air entirely. The exhauster produces a total depression of 0.25 to 0.30 meter of water, measured before the gas enters it; it leaves the exhauster with a pressure of 0.08 to 0.10 meter of water.

Gasometer.

"We have just seen that the gas is drawn through the condensing apparatus by the exhauster with a depression of 0.25 to 0.30 meter of water, and that the latter forces it back to the special burners, already described, in order to heat the ovens.

"With the coals of the company of the Mines of Campagnac, containing 35 to 36 per cent. of volatile matter, it was thought that it would not endanger the perfect operation of the ovens if 4,000 to 5,000 cubic feet of gas were taken for lighting the plant.

"This gasometer, of 2119 cubic feet capacity, is placed to the left and back of the ovens.

"It feeds about 200 burners distributed over the buildings for separating, washing, unloading, etc., etc. The gasometer is filled at the times when the gas production is greatest, that is, after the last charge.

"To effect this it is only necessary to shut off the gases from going back to the ovens, at the same time establishing communication with the gasometer. The latter is filled in a few minutes; it is then isolated and the gas from the exhauster goes again to the ovens.

"The whole operation takes about 7 to 8 minutes, during which time the coke ovens are not disturbed.

"This gas for illuminating purposes is purified by lime in two ordinary purifiers, after leaving the gasometer.

"The whole plant is thus well and economically lighted, as this gas costs a trifle.

"The products of condensation, tar and ammoniacal water, as they come from the various condensing apparatus and the hydraulic main, are all conducted into a series of settling tanks where the difference in density permits an easy separation.

"The tar is drawn off by a hand pump and put into barrels direct, ready to be sent to market. The ammoniacal waters are taken up by a pump, driven by a steam engine, and lifted to a reservoir, the level of which is higher than any of the apparatus of the plant. From this reservoir these waters go back to the first scrubber to be concentrated.

MANUFACTURE OF SULPHATE OF AMMONIA.

"The distilling apparatus for thet reatment of ammoniacal waters are a modification of the apparatus of Mallet. About 70½ cubic feet of these waters are treated at a time.

"This quantity arrives in two sheet iron receivers, which are placed side by side over a stone pier, in order to be heated at the same time in the same heating chamber. Before heating, a small quantity of lime water is put in each receiver.

"During this process, which lasts about 4 hours, the mixture is agitated from time to time with agitators for this purpose, and the disengaged gases go over into a third receiver containing 70 cubic feet of ammoniacal waters.

"This third receiver is heated by the return flame of the others and also by the vapors of ammonia, introduced into it. These vapors of ammonia, however, disengage themselves as soon as the temperature becomes high enough and are conducted into lead tanks which contain sulphuric acid and uniting with the latter yield *sulphate of ammonia.*

"During this process the sulphuric acid absorbs also the steam which the vapors of ammonia carry with them. The sulphuric acid of 60° uniting with the water yields the sulphate of ammonia in solution. The solution being evaporated, a white salt, sulphate of ammonia, is obtained with 20 per cent. of nitrogen.

"The crystallization is effected in large tanks of sheet iron, lined with lead, and having a small bottom. These tanks are 13 feet 2 inches long, 5

feet 9 inches wide and 1 foot 4 inches deep. Two of these permit, with a crystallization surface of 55 square feet, the crystallization of 660 pounds of sulphate of ammonia in 24 hours. In the double bottom of the tank steam is introduced, furnished by the boilers of the ovens. Usually 660 to 770 pounds of sulphuric acid of 60° are used, and a weight about equal to that of sulphate of ammonia is obtained.

"The work is very easy; a single man can attend to the manufacture of the sulphate of ammonia which 40 to 50 tons of coal will produce. This is the quantity which is coked daily. A boy suffices to put the manufactured tar in barrels. These two can be employed besides this for other work.

"Such are the arrangements of the works of the company of the Mines of Campagnac.

"The following statements show the cost of this plant, with the expense of making coke and saving the by-products:

COST OF PLANT—19 COKE OVENS. FRANCE.

Construction of 19 ovens	$13,177.07
Cost of each oven, $693.53	
Cost of Condensing plant	10,216.45
Cost of Apparatus—tar and ammonia	3,973.67
Cost per oven—apparatus for by-products of tar and ammonia,—$746.85, $1,440.38.	
Total cost of plant	$27,367.19

THE WORK OF OVENS IN THE YEAR 1883.

Coal charged into ovens	14,675 tons.
Coke produced	11,006¼ tons.
Showing product of coke, 75 per cent.	

Cost of labor and supplies per ton of coke and its by-products produced, $0.73 1/6.
Note.—The cost of such a plant in the United States would be about as follows:

Ovens, each	$1,000	to	$1,250
Condensing apparatus per oven	700	to	750
Tar and ammonia plant	325	to	350

Making the total cost of each oven, including chemical plant, $2,025 to $2,350, depending on localities. In France the cost would be $1,700 per oven and apparatus.

"The question may now be raised, if this mode of carbonization from top down, giving such good results with coals rich in volatile matters, may also be applied to any other coals that will coke.

"We are convinced that it will be advantageous to coke coal containing the 24 to 25 per cent. of volatile matter. The coals of Campagnac contain 22 per cent. of combined carbon, of which 50 per cent. remains in the coke.

"But it is difficult to estimate beforehand, what amount of the combined carbon of a given coal will become disengaged and unite with the coke.

"As to coals having less than 24 to 25 per cent. of volatile matter and yet capable of coking, the ovens of Campagnac will give excellent results, if used as an ordinary oven, dispensing with the gas condensing and by-product saving plant. In fact they will always be better than the ordinary ovens, as they develop fully the coking qualities of the coal, especially if communication be established on either side, between the retort proper and the top wall flue *D*.

"This communication should be established as near the outside as possible, at *O*. Each oven will thus have two openings through which the gases of distillation are emptied into the top wall flue, and their coming in contact with air, drawn into the flue by the depression of the chimney, will ignite them.

"If the doors and charging holes are hermetically sealed with clay, the coking process will proceed exactly in the same manner, as if the ovens were heated with purified gas from the condensing plant.

"As the carbonization goes from the top downward in a sealed retort, which has only two openings for the gas to escape, the dissociation of the gases and deposits of part of their combined carbon with the coke, is exactly the same as in the ovens at Campagnac.

"As it is easy to control the amount of air necessary for combustion, and all the gases of distillation yielded by the charge of coal are forced to pass through all the flues, it is easily understood, that in such an oven the maximum temperature is reached, which the volatile matter of the coal can furnish.

"We can also arrange a group of mixed ovens for carbonizing coals of 20 to 25 per cent. of volatile matter, and save the by-products of only a number of the ovens. It will thus be seen that these ovens give better results, than many other systems, especially when coal fairly well adapted for coking is used.

"By a most simple arrangement, which does not cause any additional cost in the construction of the ovens, hot air can be introduced into the combustion chambers instead of cold air.

"We would always recommend this arrangement, when coals not rich in volatile matter are carbonized.

"The results obtained from hot air have been entirely conclusive."

"From the preceding statements, of the cost and work of this coke oven, it is evident that it is well designed for coking coals inheriting medium volumes of volatile combustible matters, securing a maximum quantity of deposited carbon, from the hydro-carbons evolved in coking.

"And as previously noted, it can be used to full advantage in the manufacture of coke without the saving of by-products as well as in making coke with the saving of tar and ammonia, at the option of the management.

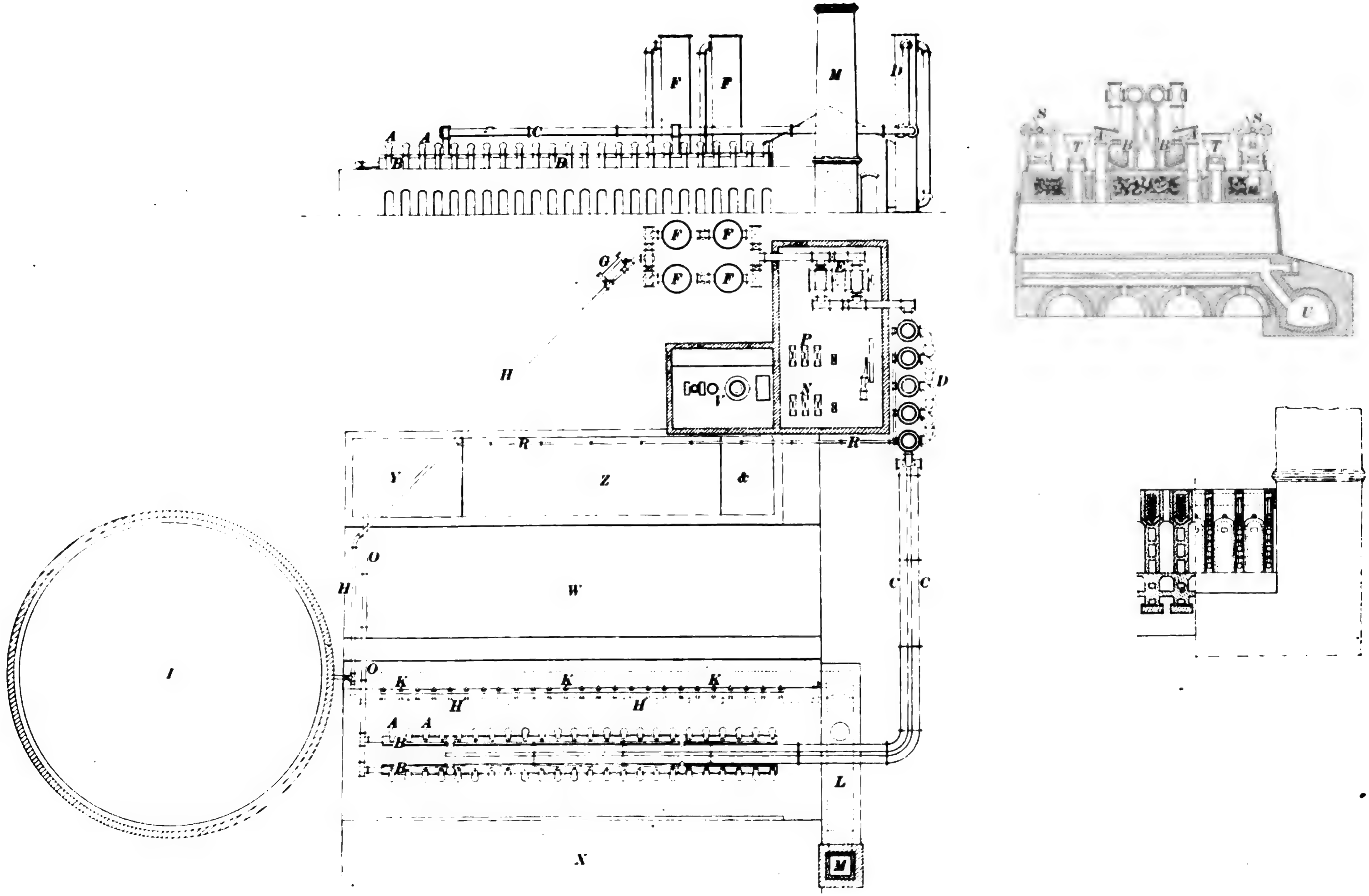

Fig. 52⅛.—GENERAL PLAN OF 24 RETORT COKE OVENS, WITH SAVING OF BY-PRODUCTS. SEIBEL'S SYSTEM.
WALTER M. STEIN, METALLURGICAL ENGINEER, PHILADELPHIA, PA.

Through the courtesy of Mr. Walter M. Stein, Metallurgical Engineer of Philadelphia, we present in Fig. 52½ a general plan of 24 retort coke ovens with saving of by-products, with the following description:

Each oven has two escape pipes *A*, by means of which the gases reach the hydraulic main *B* and are then drawn by a Beale exhauster through the pipe line *C* into the five condensers *D*, consisting of concentric cylinders. The Beale exhausters are provided in duplicate to prevent any stoppage of the plant. Each one, however, is sufficient to exhaust the entire gas of the 24 ovens. From the Beale exhauster the gas is forced through the scrubbers *F*. Two of these are ordinarily used and two are reserve scrubbers. After the scrubbers follows the steam exhauster *G*. The pipe line *H* conveys the gas back to the ovens to heat the same. A branch connection is used to fill the gas-holder *I*, which has a capacity of 52,000 cubic feet. This gas can be used for heating or illuminating purposes. The small branch pipes *K* of the pipe line *H* take the gas into the horizontal wall flues of the ovens, the gas being admitted either into the top flue only or into all of the three wall flues. The boiler *L*, is heated with the waste gases, while the surplus gas may also be used for this purpose. *M* is the chimney; *N*, three steam pumps; *P*, three reserve pumps; *O*, the pipe line to take the products of condensation to the reservoirs from the hydraulic main, and *R* the pipe line from the condensers to the reservoir. *S* is the windlass for raising the door of the ovens; *T*, *T* the charging larries; *U* the main gas flue and *V* the ammonia machine for making sulphate of ammonia. If the gas is used for illuminating purposes a purifier is inserted before the gas holder. *X* is the coke discharge side of the ovens; *W* the machine side where pusher works; *Y* is the reservoir for tar and *Z* the reservoir for strong water of ammonia, while *&* is the reservoir for weak water of ammonia.

OTTO-HOFFMAN COKE OVEN.

RETORT COKE OVENS.

In the manufacture of coke for metallurgical uses, the main effort is usually directed to the production of hard bodied coke, with a full developed cellular structure.

It adds materially to the value of such coke, both as regards purity and calorific vigor in the blast furnace, to cause as large a deposit of carbon, from the volatile hydro-carbon gases evolved in coking, as is possible from the quality of the coal used in making the coke.

Hence, in all retort coke ovens, two special requirements are demanded —the saving of the fixed carbon of the coal in coking and the securing of of a deposit of carbon from the evolved gases.

In addition to these, during the past decade, very much attention has been given in Germany, France and England, to saving the by-products of

tar and sulphate of ammonia, which are carried out in the gases during the process of coking the coal.

The initial efforts in this direction were greatly retarded by prejudices against the quality of the coke produced.

It is quite probable that these had some foundation, as the early retort coke ovens were incomplete in their operations, and their product of coke somewhat below the standard requirements. Besides, gas house coke was looked upon as a retort coke and considered inferior, as it was in fact, for metallurgical uses, as compared with the carbon glazed coke from the Bee-Hive ovens.

The recent improvements in retort coke ovens have nearly, if not quite, removed these objections, and retort oven coke is now afforded an unprejudiced test on its merits.

In the European countries, with agricultural conditions requiring concentrated manures, the by-product of sulphate of ammonia has become a valuable adjunct in the manufacture of coke, with the assurance of a home market for all that can be produced.

In the United States of America, the conditions requiring the use of concentrated manures are somewhat different, as there is still a large proportion of virgin soil that requires little manure; yet in many sections of the country the sulphate of ammonia could be used to advantage by the agriculturists.

Just how far the American coke manufacturers desire to invest in by-product appliances to their coke oven plants, is a business inquiry demanding earnest and exhaustive consideration.

In the presence of a gradually approaching time, when the use of the secondary qualities of coking coals becomes necessary, it is evident that the retort coke ovens will come into more general use, in the manufacture of coke for blast furnace and kindred uses.

The work of the Bernard, Seibel and Semet-Solvay retort coke ovens have been fully submitted in previous sections. These ovens can be used either with or without the auxiliary appliances for saving by-products.

We are further indebted to Dr. C. Otto & Co. of Delhausen on the Ruhr, for developing the Otto-Hoffman retort coke oven, which has, in a great measure, removed the prejudices against retort coke, previously noted.

The following description of this oven is taken mainly from the paper of B. Leistikow, general director of the Wilhelmshuette.*

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* Address delivered on Sept. 5, 1892, at the fifth general meeting of the German Mining Engineers.

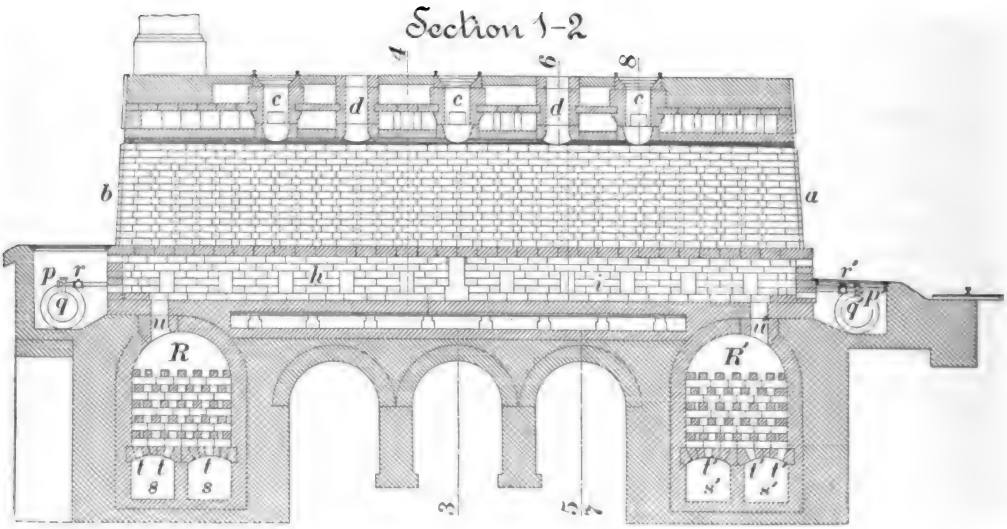


FIG. 53.—LONGITUDINAL SECTION OF AN OTTO-HOFFMAN COKE OVEN.

The Otto-Hoffman ovens are narrow chambers 16 to 24 inches wide, 33 feet long and 5 feet 3 inches high to the base of the arch, and are closed at both ends by air tight doors.

The construction of these ovens is based on a combination of the Siemens regenerator, according to Hoffman, with the ordinary Otto oven as a model, to which a large number of improvements have been made.

On the accompanying drawings, Fig. 53 exhibits a longitudinal section of an Otto-Hoffman coke oven. On the side *a*, is the pushing engine; the coke is discharged on the side *b*, on which it is cooled. There is no direct connection with the coking chamber and the side flues.

In the covering arch there are three openings *c*, which are ports for charging coal into the ovens, and two openings *d*, through which the gases evolved in coking pass off.

Under the base of the arch, in the side walls, there are horizontal flues *e*, Fig. 54, which connect the entire vertical draft system.

The base flues *f*, running lengthwise of the oven, are divided by the side walls *g*, into two equal parts *h* and *i*. Each of these halves is connected with regenerators *R*, *R'*, used for pre-heating the air necessary for the combustion of the gases.

To each half of these base flues, tuyere pipes *p* and *p'*, are connected, which are fed through the gas supply pipes *q* and *q'*.

The regenerators are long, latticed brick flues, running across the whole coking chambers. They are connected at one end by means of a reversing valve, either with the air-distributing pipe *k*, Fig. 55, or back with the chimney.

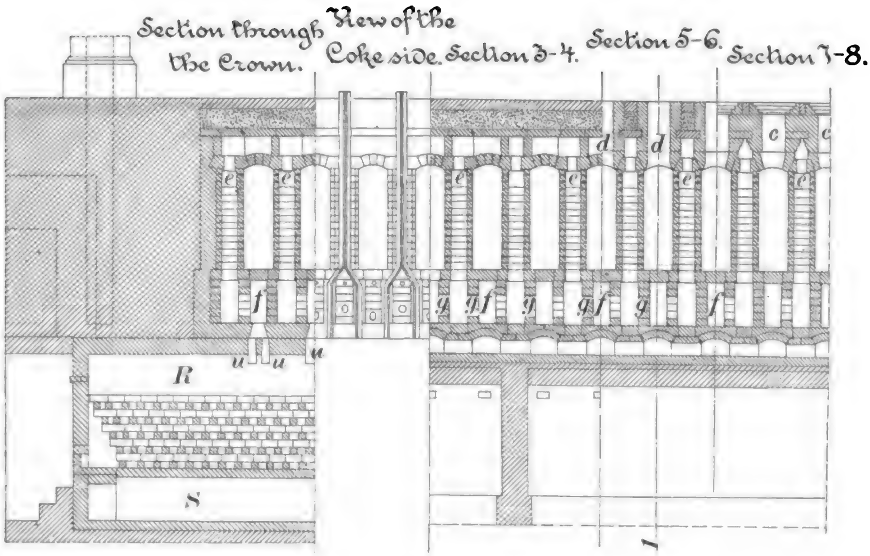


FIG. 54.—TRANSVERSE SECTIONS OF AN OTTO-HOFFMAN COKE OVEN.

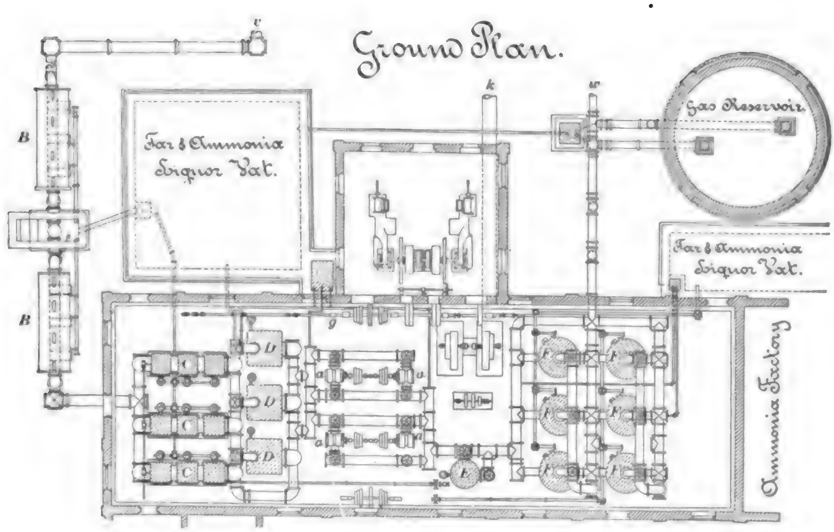


FIG. 55.—CONDENSATION PLANT AT THE JULIENHUTTE.

As soon as the oven is heated and the coking process in operation, the gases evolved escape through the openings, *d*, *d*, into the supply pipe, similiar to the retorts in gas plants, and from thence through the opened valve into the gas receiver, from which they pass through the conductor, *v*, to the condensation plant.

From the latter, the gases, freed from their by-products, tar and ammonia and benzol, are returned to be burned around the ovens. On the way to

the latter is a reversing valve, which leads the gas at will into the supply pipe, q or q'.

When the gas enters through the pipe, q, and passes through the tuyere, p, by means of the cock, r, into the half, h, of the base canal, then the valve is so set, that blast enters the flue, s, and thence through the small opening, t, into the regenerator, R, and is heated there, passing upwards through the small openings, u, u', into the base flue, h, where combustion takes place. The heated products of combustion pass through the side vertical flues, then to the horizontal flues, e, and quickly downward through the other vertical half to the base flue, i, from thence through the opening, u', into the regenerator, R', heating it and passing it through the small openings, t, into the flues, s', s', and from thence through the air valves to the chimney.

The valve is reversed after a certain time, and the gas takes exactly the opposite direction.

In the earlier work of this oven, it was thought necessary to pre-heat the gas as well as the air; for this purpose a second regenerator was arranged on each side of the oven, this, however, was discontinued, as it was found to be better to heat the necessary air, amounting probably to ten times the volume of the gas, to a high temperature, than to heat the comparatively small volume of gas, thereby running the risk of explosions.

In all later plants, there is arranged on each side of the ovens, only one regenerator, as shown in the accompanying drawings, by which change this oven has been much simplified without impairing its utility.

The air is first pre-heated in these regenerators to about 1,000° C., thereby reducing the amount of gas necessary to heat the ovens, leaving the excess for other purposes.

The gases evolved from the ovens pass through the valve into the receiver and are aspirated into the condenser by the aspirator A; on its way to the condenser the gas passes into an apparatus B, wherein it is cooled and separated from particles of coal dust and a great deal of the tar.

The gases now pass into the condenser C, consisting of a vertical, four cornered wrought iron box, supplied at the top and bottom with false floors, on which are arranged a large number of wrought iron tubes, through which cold water flows.

The gases travel around the tubes in an opposite direction, while the products of condensation—tar and ammonia continually run off below.

The water of the coal passes off as steam, absorbing about 50 per cent. of the ammonia.

After the gases have passed the cooler, they arrive at the purifier D, which is quadrangular, and the gas divides itself into a number of tubes, which are immersed in water.

In the purifier, the gas is first washed with pure water and then with weak ammonia water, and the remainder of the tar is separated. The

apparatus is so constructed that the water flows in from above and out below continuously.

This water, together with the condensed products of the air and water coolers pass into a large vat, where the tar separates by virtue of its specific gravity.

The same aspirator can be used for forcing out the last particles of gas, which becoming heated several degrees by the sudden compression, must be passed through another cooler *E*, to reduce them to a minimum temperature 13° to 18° *C*.

After leaving cooler *E*, the gas streams below into the bell washer *F*, where it is distributed amongst a number of bells, which have a toothed diaphragm extending under the water, whereby it receives a thorough scrubbing.

The washer contains 4 to 6 shelves, one under another, and the water flows from above downward; the gas takes the opposite direction and always is driven against the fresh stream of descending water, whereby it is completely separated from the least traces of tar and ammonia.

The purified gas may now be conducted to the ovens for combustion, unless it is desired to separate further products, notably benzol, which is done in some works. the process, however, being secret.

The gas, before being forced into the pipes, *q* and *q'*, is led through a small reservoir, which acts as a pressure regulator, and indicates to the inspector, whether the pressure is constant, which is necessary to insure constant temperature in the ovens.

The temperature was found to be as follows:

In the hearth flue	1200° to 1400° C.
In the side walls	1100° to 1200° C.
In the regenerators at the beginning of the air supply	1000° C.
In the regenerators at their ends	720° C.
In the chimney	420° C.

The tar which separates at the bottom of the vat by reason of its weight, is conveyed by a wall pump operating a spiral conveyor to the high receiver *H*, Fig. 56, from which it may be run directly into cars and taken to the refineries.

The ammonia water, which has collected in the vats, is pumped to the receiver *T*, from whence it is piped to the distilling room of the ammonia factory.

In this latter are two "Colonnen" apparatus *O*, of the Grueneberg-Blum system (in other works they use Dr. Feldmann's apparatus with equally good results), each capable of working 30,000 litres, in which the water passes downwards from column to column, coming in contact with a current of dry steam, which takes out the ammonia and carries it with it. See Figs. 56 and 57.

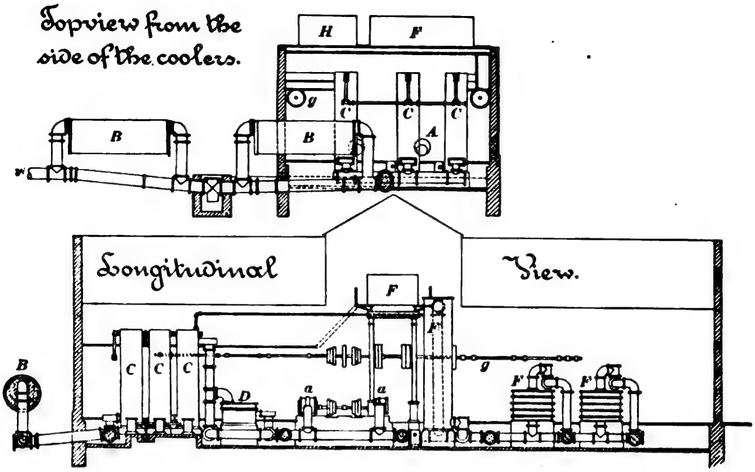


Fig. 56.—CONDENSATION PLANT AT THE JULIENHUTTE.

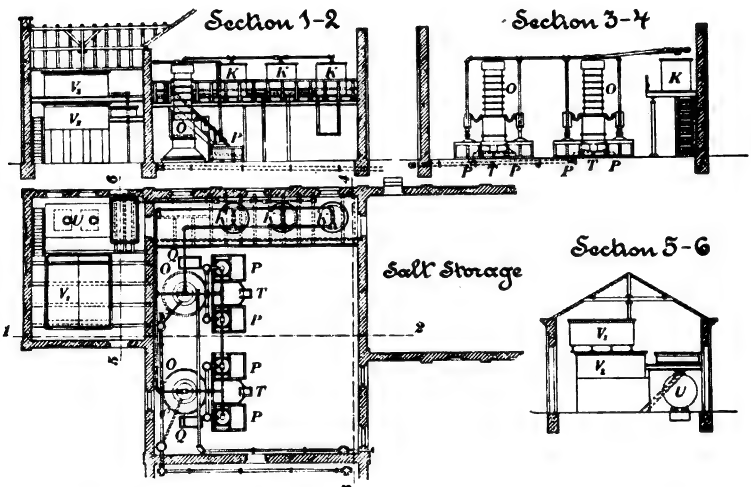


Fig. 57.—AMMONIA FACTORY AT THE COKE OVEN PLANT OF THE JULIENHUTTE.

The ammonia is set free from its compounds by milk of lime in the space above the cascade column, which is pumped into the apparatus from the lime reservoir *Q*.

The steam, saturated with ammonia, is led into sulphuric acid in the lead lined chambers *P*, where it is converted to ammonium sulphate, or into the condenser *K*, where it is taken out as ammonia water. When the chamber acid is neutralized the liquor is drawn off and the salt removed to the dropping board *T*, from whence, when the lye has entirely drained, it will be transferred to the lead lined salt chambers.

On the other hand, if the ammonia water is simply condensed in the cooler *K*, it runs into the receiver *U* (holding about 10 tons), from whence

it may be piped into tank cars for transportation. The sulphuric acid may be stored in the receiver *V*, to be run off by means of air pumps or siphons as needed, into the boxes *P*.

The waste water, which runs off from the apparatus *O*, is led into vats, where the lime settles out.

The plan and sections at Figs. 56 and 57, exhibit a view of Plant 3, of the Julienhuette, at Buethen, in East Silesia.

The cost of this oven and the distillation apparatus *in Germany* is as follows:

The cost of oven	$ 1168.75
By-products apparatus, per oven	1636.25
Total	$ 2805.00

This cost would be largely increased in the United States—especially as the apparatus for the saving of the by-products are erected in duplicate.

This duplicate apparatus affords the opportunity of cleansing, and repairing the several parts of these appliances without interruption to the continuous work of the ovens.

It adds to the expense in the construction of the plant, but it is found to be an element of economy in the working of these retort ovens.

The Otto-Hoffman oven is usually constructed in sections of 60 ovens each. A duplicate apparatus for condensing and exhausting will serve for two sections of ovens.

The cost of these ovens in the United States has been estimated at $3,300 each.

This includes the necessary apparatus for the saving of the by products of tar and ammonia sulphate.

This cost does not cover the patent charge for using this oven.

In the estimates of the value of the by-products secured, per ton of coke made, very large claims have been submitted.

With the use of good coking coal, the net profits have been estimated as high as $1.52 per net ton of coke produced. It may be pointed out that this estimate includes the value of 40 per cent. of surplus gas for heating purposes, which is calculated at 14 cents per ton of coke.

It is evident that such an estimate is misleading, when it is considered that tar is now worth at the coke ovens $5 per ton, and ammonia sulphate $55 to $60 per ton in market.

An average product of about 1 per cent. of ammonia sulphate and 3 per cent. of tar can be secured from the carbonization of coal to make 100 tons of coke. Under present conditions the value of these at the coke works is $50 and $15, making in all $65, less the cost of manufacturing the sulphate of ammonia, $34 per ton, leaving as the maximum net profit per 100 tons of coke made, $36, or 36 cents per ton.

The value, per ton of coke, of surplus gas from the ovens will be somewhat different, depending on the value of coal in the locality of the coke ovens. An average of 5 cents per ton would be a safe estimate.

This, added to the value of the by-products of tar and ammonia sulphate, affords a net saving of about 41 cents per ton of coke produced.

A reference to table No. IV will afford full details.

Dr. F. Schniewind, of Cleveland, Ohio, who formerly represented this oven in the western section of the United States, writes:

As to the life of the plant, the construction of the ovens in all details is most substantial, reducing repairs to a minimum.

At Hoerde, Westphalia, there is a plant, making coke without saving by-products, that has been running the past thirteen years and requiring very moderate repairs.

The coking coal used in Germany is very different in quality from the American standard, the Connellsville coal.

It is, as regards coking qualities, poorer throughout.

In Westphalia, in the Ruhr basin, the most important coal and coke district in Germany, the coal varies in its character in a similar way as in the Appalachian field; the coal becoming more bituminous in a gradual increase from the east to the west. This gives a variety of qualities of coal for coking, depending on the locality of the coal supply.

The yield of coke varies from 70 to 85 per cent. of coal charged into ovens.

The following may be considered an average analysis of Westphalian coking coal washed:

Volatile Matters	23.00	per cent.
Fixed Carbon	67.70	"
Ash	8.00	"
Sulphur	1.30	"

The theoretic yield of coke would be about 76.48 per cent. The washed coal is charged into the ovens in a very moist condition, holding about 12 per cent. of water. The coke, though it cannot be compared as to luster with the Connellsville coke, yet is an excellent blast furnace fuel, which stands a heavy burden in the furnace.

The fuel results of the German blast furnace are very good indeed, if the poor quality of the coke making coals is considered.

In Silesia the coking coal is of very poor quality. In some instances extraordinary measures have to be resorted to in order to produce coke; the coal has to be disintegrated finely and then while moist stamped by hand into large sheet iron casks and charged into the oven. It is only in this way, and by the use of the Otto-Hoffman ovens at a very high temperature, that a coke suitable for blast furnace use can be made.

In the Saar district the coal is also very poor.

In all these different districts many Otto-Hoffman ovens are in operation, producing as good coke as possible under existing conditions.

TEST OF THE CONNELLSVILLE COAL IN THE OTTO-HOFFMAN OVENS.

In order to investigate the results that might be expected from these ovens when running on Connellsville coal, I went over to Europe early in the Summer of 1893, in the company of a competent American blast furnace engineer, who was sent by some capitalists who had become interested in this matter.

This gentleman examined closely all the different systems in use abroad and came to the conclusion that the Otto-Hoffman oven and condensation plant are the best.

His recommendation and the excellent results of the tests, which exceeded our most sanguine expectations, would have doubtless led to the erection of the first plant in this country, if the unfortunate financial calamity had not set in.

We had sent to Europe about 18 tons of Connellsville coal, with which, after some preliminary tests, we charged whole ovens.

The coke made was of most excellent quality, very hard, with metallic ring and silvery luster.

It was impossible to discriminate this coke from the original Connellsville Bee-Hive coke made from the same seam of coal at the H. C. Frick Coke Company's Valley Works, from whom we had procured the coal.

The only apparent difference was in the size of the pieces of coke; as the retort oven coke pieces were only about one foot long.

The pieces from the Bee-Hive oven were somewhat larger, but this could not be regarded as a marked advantage.

Some of this coke was placed on exhibition in the recent mining exposition at Gelsenkirchen, where it caused general admiration, as not a single brand of Westphalian coke could compare with it.

The Connellsville Coal was composed as follows:

Moisture	1.59	per cent.
Volatile Matter	29.18	" "
Fixed Carbon	58.84	" "
Ash	9.40	" "
Sulphur	0.99	" "
	100.00	

The theoretic yield of coke from the above coal is about 68.84 per cent. In the Otto-Hoffman ovens the products were:

Large Coke	71.1	per cent.
Small Coke	1.2	" "
Braize	1.3	" "
	73.6	

This result shows, assuming that no fixed carbon has been burned in coking, a deposit of 4.76 per cent. of carbon from the hydro-carbons in coking. The result is evidently correct, as the rich coking coals of Connellsville or West Virginia secure carbon deposits in the coke oven.

The time occupied in coking Connellsville coal in the Otto-Hoffman oven was from 28 to 32 hours.

As to the yield of by-products, the Connellsville proved to be equal to the richest German coals, as will be seen from the figures based upon dry coal.

Locality.	Per cent. coke and braize.	Per cent. tar.	Per cent. sulphate of Ammonia.	Cubic feet Gas, per net ton of coal.
Connellsville coal............	73.6	4.0	1.07	9821
Westphalian coal............	76.0	3.0	1.15	8744
Silesian coal..................	67.0	4.2	1.12	10067

In regard to benzol the yield from Connellsville coal will be found richer than that from German coals, which yield from 0.3 to 0.7 per cent. from dry coal. It is difficult, however, to make any accurate statement as analytical research is insufficient.

The quality of the by-products obtained from Connellsville coal was excellent.

The excess of gas, about 40 per cent. of the total production, is of great value for illuminating and heating purposes.

As a source of light it has only about one-half the illuminating power of best illuminating gas, if used with ordinary burners; but if used with the modern incandescent burners, its light equals in brilliancy the electric incandescent lamp.

The fuel value may be judged from the following comparative table.

Analyses 1 and 3, by Dr. Knublanch—2, 4, 5, 6, 7, by W. J. Taylor, A. I. M. E. Vol. XVIII, page 881. No. 8, by the agents of the English or Smith oven.

The comparison, especially of the percentage of nitrogen, will show the efficiency of the Otto-Hoffman oven.

At most plants the surplus gas is used for generating steam in boilers, together with the off-heat from the regenerators.

The steam produced is 0.9 pounds of 4 to 5 atmospheres pressure for each pound of dry coal coked in the ovens. This is the average result of 48 hours run (if the time of coking is reduced, the evaporation of water increases) and after all the by-products, including benzol, have been recovered.

TABLE OF ANALYSES OF DIFFERENT GASES.

Percentage by volume.	Gas from Otto-Hoffman ovens. 1.	Coal gas, average American 2.	Coal gas, Cologne, Germany. 3.	Natural Gas. 4.	Water gas. 5.	Producer Gas. Anthracite. 6.	Producer Gas. Bituminous. 7.	Gas from Improved Bee-Hive ovens. 8.
Hydrogen.........	53 82	46.0	55.0	2.18	45.0	12.0	12.0	2.3
Methylene.......	36.11	40.0	36.0	92.60	2.4	1.2	2.5	18.7
Ethylene..........	1.63	4.0	1.19	0.31	....	....	0.4	0.9
Benzol	0.61	?	1.54	....	....	....	....	....
Carbon Monoxide.	6.49	6.0	5.40	0.50	45.0	27.0	27.0	2.6
Carbon Dioxide...	1.41	0.5	0.87	0.26	4.0	2.5	2.5	9.8
Sulph. Hydrogen..	0.43	?	?	....	....	....	....	....
Nitrogen..........	....	1.5	....	3.61	2.0	57.0	56.2	70.0
Oxygen...........	....	0.5	....	0.34	0.5	0.3	0.3	0.7
Vapor	....	1.5	....	....	1.5	....	....	....
	100.	100.	100.	99 80	100.4	100.	100.9	100.

The market for the by-products of tar and the sulphate of ammonia is reported as fairly good, with an upward tendency.

The demand for tar has been increased by the change in the methods of making illuminating gas at the gas works.

This has been brought about by the use of coke and steam in the place of gas coal in the old time practice.

The recent methods afford no tar in the manufacture of illuminating gas, hence the increased demand for tar from the by-products in coking coal.

The following table exhibits the imports from England of the sulphate of ammonia during the years from 1890 to 1893, inclusive, with prices for same in New York City:

Years.	Pounds.	Price, New York per Net Ton.	Remarks.
1890..............	4,308,367	$63.45	From England
1891.....	34,622,079	62.88	" "
1892..........	14,349,362	59.38	" "
1893..............................	18,794,599	66.14	" "
At close of 1893	....	73.60	" "

It is submitted that Cleveland affords a good market for these by-products.

The following valuable paper of Dr. Bruno Terne, was read before the chemical section of the Franklin Institute, Philadelphia, Penna., October

20, 1891. It exhibits Dr. Otto's efforts in utilizing the Bee-Hive type of coke oven for saving the by-products of tar and ammonia.

THE UTILIZATION OF THE BY-PRODUCTS OF THE COKE INDUSTRY.

BY DR. BRUNO TERNE.

[Read at the stated meeting of the Chemical Section, held Oct. 20, 1891.]

About a year ago I had the honor to speak in the lecture course of the Franklin Institute on ammonia, its sources and technical uses.

I dwelt, for reasons which I thought of sufficient importance, especially on the production of ammonia as a by-product of the coke industry.

We have now entered upon the beneficial workings of the new policy of furthering industrial developments in new branches in a period which requires the technical men in all branches, and especially in the chemical industries, to call the attention of the capitalists to the points in which we are behind the times in our developments, to the points where the resources of our own land are neglected, and we are far behind the more progressive European manufacturers.

I thought it of sufficient importance to ventilate the same question before the Chemical Section of the Institute in order to create an interest in the circle of the members of the institute, who are the best judges of such questions, in order to provoke criticism of my views.

I have revised the part of my lecture referring to the development of the ammonia industry for this purpose, not in the expectation of claiming new and original ideas, but to secure your attention to a point which I consider of great importance for the development of an important branch of the chemical industries.

We are surrounded by an immeasurable quantity of nitrogen gas in the atmospheric air.

The weight of the atmosphere surrounding our earth is calculated to be ten trillions of pounds, of which 7.77 trillion pounds are nitrogen; but in spite of this inexhaustible source of nitrogen, we are not able, in a direct way, to use a single pound for the production of ammonia.

It has long been the endeavor of the technical chemist to convert the nitrogen of the air into ammonia, but up to this hour none have succeeded in doing it with practical results. We are still compelled to use as sources for the production of ammonia the products of plant or animal life.

The nitrogen of the air must pass through the channels of plant life to reach in the products of the animal body their highest degree of concentration.

Hoofs and horns with fifteen to sixteen per cent.; dried blood, with nineteen per cent.; hair and wool waste, with ten per cent.; and bones, with five per cent. of ammonia, are the richest sources.

But the products of animal life, however, even if they were not too valuable otherwise, are by no means sufficient to satisfy the wants of the

present day for the products of ammonia. But nature has provided an inexhaustible source for hundreds of years to come, in the residuum of plant life of former periods. In the bituminous coal fields and in the deposits of brown coal are lying stored up, billions of pounds of nitrogen waiting to be converted into ammonia.

The process of gaining this ammonia is incidental to the production of illuminating gas, to the production of coke, and to the production of animal charcoal.

In distilling the bituminous coal we obtain of the weight of coal used:

4–6 per cent. of tar and 6–10 per cent. of ammoniacal water of 1°.8 B.

As Prof. Lunge has shown, the nitrogen contained in the coal does not yield the amount of ammonia which we might expect:

Name of Coal.	Yield of Nitrogen. Per Cent.	Possible Yield of Ammonia. Per Cent.	Possible Yield Ammonia Water. 1.020 spec. grav. Per Ton of Coal. Gallons.
Wales	0.71	1.10	142
Lancashire	1.25	1.52	196
Newcastle	1.32	1.60	206
Scotland	1.44	1.75	226

But instead of these figures, the practical yield per ton of coal at the best is only forty-five gallons of gas water of 1.020 sp. gr., generally only twenty-five gallons, and in some instances, as low as thirteen gallons.

The ammoniacal liquors from distillation of animal refuse are much richer, but the small quantity produced allows us to ignore the same as a very insignificant factor in the production of ammonia salts.

The consumption of ammonia in its various forms has grown enormously in the last twenty years, and the manufacture of illuminating gas is no longer sufficient to supply the increasing demand for ammoniacal liquors. On the other hand the inroad which electrical plants for illumination have been making yearly on the production of illuminating gas, has already been felt, and will be more so from year to year. The production of water gas and oil gas are other factors which are cutting down the amount of ammoniacal waters produced.

But there is another source for tar and ammonia, which, so far as my knowledge goes, has, with a single exception, not been worked in our country.

Rich as are our resources, we are not rich enough to waste continually.

It seems strange, and nevertheless it is a fact, with all the ingenuity of the American people in the advancement of the purely mechanical part of the technical industries, we have been and are yet slow in the development of the chemical industries.

The acid manufacturer of Europe, especially of England and Germany, had commenced in the beginning of this century to make himself independent of the sulphur mines of Sicily by using the sulphurous ores of his immediate neighborhood, and to utilize the pyrites for making his sulphuric acid. It has been only within the last twenty years that our people commenced to use the ores which had been lying under their feet, and to-day even, the United States consumes more sulphur for the mannfacture of sulphuric acid than any other nation.

It is the same with productions of tar and ammonia as a by-product of the manufactures of coke.

If you will visit our coal region to day, you will find the nightly sky illuminated from the fires of the coke ovens, and every one of the brilliant fires bears testimony that we are wasting the richness of our land in order to pay the wiser European coke manufacturer, who saves his ammonia and sends it to us in the form of sulphate of ammonia; and who also saves his tar, which, after passing through the complex processes of modern organic chemistry, reaches our shores in the form of aniline dyes, saccharin, nitrobenzol, etc.

As far back as 1768 tar had been produced as a by-product of the coke industry by a chemical process at Fishbach, in the coal district of Saarbrücken on the Rhineland.

The general opinion of the consumer there was then, and most likely will be here at the present time, that the coke produced will be of inferior quality. Against this opinion of the practical coke men, it has always been held by technical chemists, that the process can be so conducted as to yield all the by-product and still make a first-class coke.

Since about 1850, the producers of coke in France, Belgium, England and Germany commenced simultaneously the saving of the by-products.

At St. Etienne, in France, a system of furnaces was at work in 1862 for which great success was claimed at that time. The gas and other volatile products of the coke oven were conducted to an air condenser, in which the tar and ammonia were condensed; the non-condensable gases were returned to the furnace as fuel.

Scrubbers and condensers have been improved to insure complete condensation.

The following average results have been claimed:

	Per Cent.
Coarse coke	70
Small coke	1½
Waste coke	2½
Graphite	½
Tars	4
Ammonia water	9
Gas	10.58
Loss	1.92

The net gain after deducting all expenses and without reckoning in the coke was, per oven, in Bessèges, which has eighty-five ovens in operation, 111,446 francs. For eighty-five ovens this saving amounts to 94,990 francs or about $18,938.

I give you in the accompanying table, the results reported from two establishments in France.

I will not endeavor to cover the development of the coke industries of Europe for the whole period since 1850. I have had occasion to familiarize myself with all the conditions of this industry, and am in possession of figures and plans of Dr. Otto's successful ovens, a view of which I show you. See Fig. 58.

In 1883, a system of twenty ovens were built at the coke works of Gottesberg, Silesia, the results from which were so encouraging, that in the following year 120 ovens were built.

I will give you a report from a manufacturer, who, two summers ago, visited the Dahlhausen works of Dr. Otto, at the mines of Millensiven near Dortmund. Here there are two sets of thirty ovens each, which are charged alternately every other day. The gases are conducted by large iron pipes to a large basin, where a part of the tar will be condensed. From there it is led to the coolers, where the remaining tar and ammoniacal products are absorbed, and the gas, purified, is returned to a gas holder, and from there is redistributed to the coke ovens, to the boiler fires and utilized as illuminating gas throughout the works. The gas returning to the coke ovens is mixed with hot air, and enters the flues of the bottom and sides. The coke produced is an excellent product, and finds a ready market everywhere. It has not the silver gray or steel color of our Connellsville coke, but it is quite as good in quality as ours.

Name of Works.	Number of Ovens.	Tons of Coal Consumed.	Yield of Coke.			Tar.			Ammonia Water.		Sulphate of Ammonia.		
			Total Tons.	Prac. Per Cent.	Per Oven.	Total Tons.	Per Cent.	Per Oven.	Hectolitres.	Per Cent.	Per Hectolitre, Kilograms.	Per Oven Tons.	Per Ton of Coal, Kilograms.
1879. Bessèges	85	46,902	33,092	70.55	389.3	1,096	2.23	12.89	44,932	9.6	6.5	3,435	6.22
Terrenoire, April 1 to December 31, 1879	100	38,427	26,293	68.42	......	966	2.50	......	36,205	9.72	7.6	......	....
Per annum calculated	....	......	......	......	350.57	1,288	....	12.88	......	....	....	3,374	6.54

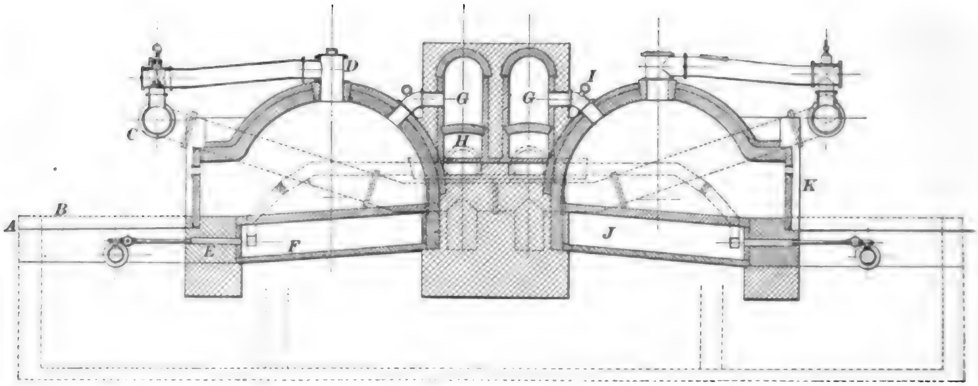


FIG. 58.—DR. OTTO'S IMPROVED COKE FURNACE.

A, Floor; *B*, Edge of Basin; *C*, Receiver; *D*, Supply Opening; *E*, Gas Inlet; *F*, Air Inlet and Exhaust of Products of Combustion; *G*, *G*, Generators; *H*, Air Channel for Distribution of Air; *I*, Valve for Heating the Ovens; *J*, Sole, heated to 1200° Celsius; *K*, Door Fastening.
Product, 75% Coke; 1% SO_3NH_3; 2½ to 3% Tar.

Dr. Otto builds these ovens at his own expense, runs them for twelve years, taking the coal from the mines and delivering the coke to the mine company, for the yield of tar and ammonia, and at the end of the term surrenders the whole plant to the mine owners. He must make in this time from the value of the by-products alone, the cost of the ovens, the interest of the capital invested and the legitimate profit of a manufacturer, and he is successful in doing it. Don't you think that we can achieve the same results here?

In the year 1887, there were in operation in 279 establishments in the United States, 26,001 ovens, and 3,594 ovens in course of erection.

These ovens consumed 11,859,753 tons of coal, producing 7,611,705 tons of coke, a percentage of 64.2. Calculated on the basis given in the table before you, the possible yield of sulphate of ammonia from this quantity of coal, *i. e.*, 12.8 pounds per ton, will give us the enormous figures of 151,804,838 pounds of sulphate of ammonia, which at three cents per pound only is equal to $4,554,746.

Pennsylvania is the principal coke-producing State in the Union.

Seventy-six and six-tenths of the coke used in the United States is made within her borders.

The number of establishments were, in 1887, 151, with 18,294 ovens, which produced 5,872,847 tons of coke, a yield of sixty-five per cent. The Connellsville district, of Pennsylvania, is one of the most important of the world. The Connellsville basin is in the southwestern part of the State, some fifty or sixty miles from Pittsburg. In this district were made 4,146,989 tons of coke, or 57.4 per cent. of all the coke made in the United States.

At three works, during the year 1886, careful weighings were carried on, with the following results:

	Coal Charged.	Coke Produced.	Per Cent. Yield.
No. 1	230,585	157,070.40	68.118
" 2	60,934	40,947.09	67.188
" 3	63,893.2	42,927.24	67.2
Total	355,421.2	240,944.64	67.8

The coal used in Pennsylvania in 1887, for making coke, was 8,938,849 short tons.

If this had been done with saving of the by-products, 178,776 tons of tar and 114,417,267 pounds of sulphate of ammonia, or $7,208\frac{1267}{2000}$ tons of sulphate of ammonia could have been produced, which represents in ammonia salt alone a value of $3,432,480; or, to illustrate in another way, 28,604,316 pounds of ammonia, which has an agricultural valuation of eighteen cents per pound, have been lost to the industrial and agricultural interests; or, at the valuation of the agricultural experimental stations, the loss of a single year was $5,128,776\frac{88}{100}$.

I am very well aware that these figures are imaginary, as under the best possible circumstances not all the coke-ovens could readily be arranged for the saving of by-products, but if one-eighth or one-half of the total production were united with saving of the by-products, from one to two millions a year on ammonia only could be produced in this State alone.

You will ask, Will the Connellsville coal give the same result as the German coal? Without hesitation, I answer, it will.

There are here five samples of coal from the Connellsville district, which have been analyzed in my laboratory, with the results given below:

	Per Cent.	
No. 1	1.76	ammonia.
" 2	1.26	"
" 3	1.90	"
" 4	1.80	"
" 5	1.80	"

These analytical results place the coal of the Connellsville region on an even footing with the bituminous coal of the district, where the by-products of coal are gained in making coke.

There are numerous systems of coke ovens in Europe, but none has been more successful than the ovens mentioned above. Whatever the system may be, the products of condensation must be separated; the tar from the ammoniacal waters, and each worked according to its specific requirements. In England, the escaping gases of blast furnaces have in two instances been worked for ammonia. I am unable, however, to say anything about results.

The interest of the manufacturer of ammonia requires that the liquors should be as concentrated as possible, and still leave the gases escape as

free as possible from ammonia. To accomplish this, certain improvements in apparatus have come into use. The older construction of scrubbers, or apparatus for washing the gases, has been superseded by mechanical scrubbers. One of the latest constructions of such a scrubber is that constructed by the Director of the City Gas Works, in Chemnitz, Saxony, and adopted by the best authorities of Germany as one of the most economical working forms of the apparatus.

The mechanical scrubber of E. Ledig* is based on the principle of the rapid absorption of ammonia by water distributed over a large surface, which is heated by a system of plates alternately dipping in water and raised out again, thus offering the gas the large surface of the combined plates. This up and down movement creates new surfaces for absorption with each motion, and secures a complete washing of the gas. The ammoniacal liquor so gained has now to be worked so as to gain the ammonia from it in order to prepare the different ammonia compounds.

The ammoniacal liquors contain free ammonia, carbonate of ammonia, sulphide of ammonium, sulphocyanide of ammonium, tartrate of ammonia, sulphite of ammonia, chloride of ammonium, sulphate of ammonia, organic ammonia compounds, such as amin, pyridin, etc.

The ammonia waters contain in one litre, from coals of the

		Grammes.
District	Zwickau (Saxony)	37,943 ammonium salts.
"	Ruhr (Rheinland)	29,402
"	Saar "	43,225
"	" "	9,506

You will notice that the differences in yield are very wide, but nevertheless the smallest amount named is sufficient to make the gain of the by-products, in the commercial scale, a profitable operation.

The oldest methods of gaining the ammonia were to saturate the liquors directly with sulphuric acid in large tanks. The cost of evaporating such enormous quantities of water and the impure condition of the product soon led to the invention of improved methods.

Tanks, or a system of tanks, were heated directly by fire or steam, and the volatile ammonia driven out to be absorbed by the acids in the receivers.

The newest improved forms of apparatus are those constructed by the well-known manufacturer of chemical products, Dr. Grüneberg, of Cologne, and by Dr. Feldmann, of Bremen. Both of these are constructed on the same principle, viz: a current of steam moves in opposition to the movement of the liquor. The richest liquor comes in contact with the nearly saturated vapors and the weakest liquor with the fresh steam.

These forms of apparatus have superseded in Europe, especially in England and Germany, the older devices.

* U. S. Patent, No. 407,937, July 30, 1889.

The accompanying engraving, Fig. 59, shows the construction of the Grüneberg apparatus.

The apparatus of Dr. Feldmann as still simpler and is, therefore, preferred by a great many manufacturers of ammonia salts. See Fig. 60. Both of these devices are patented in the United States.

The Feldmann apparatus cannot be excelled for economy of steam and reliability in service; its capacity for working five to twenty-five tons of liquor daily makes it likewise desirable for a rural gas works as well as large establishments.

The question, Will it pay to gain the by-products of the manufacture of coke? has been practically solved in the affirmative. The numerous objections have, step by step, been overcome. The industry of the coke production combined with the saving of the by-products is an established fact in Europe, and will be here also in the near future. What system of

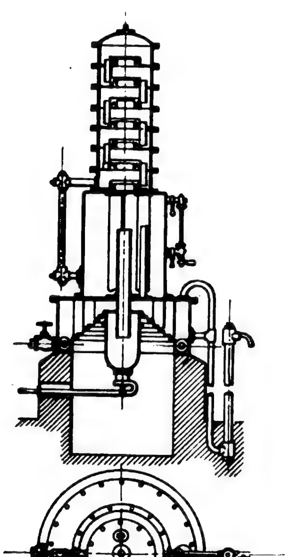


FIG. 59.
THE GRÜNEBERG AMMONIA STILL.

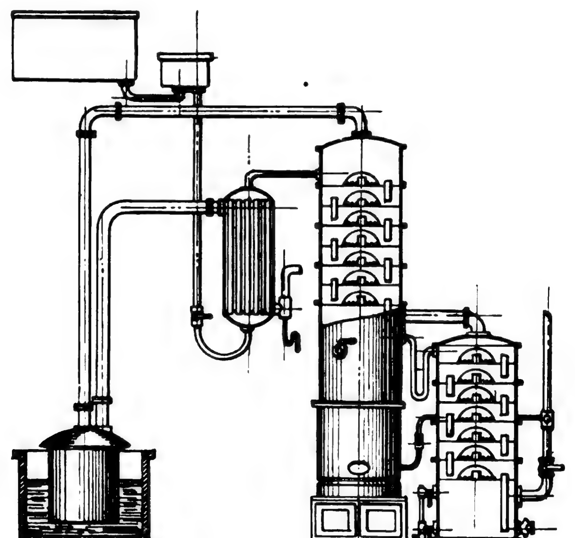


FIG. 60.
THE FELDMANN AMMONIA STILL.

ovens will be found best adapted to our wants, may be an open question, to decide which rightly will require the consideration of a great many points of local importance.

The system which I have described is one of the most successful of those used in Germany to-day.*

I advocate the Otto system because I know of its merits and advantages from a careful study of it, and lengthy correspondence with the inventor.

* The latest improvements are covered by D. R. P. 52,206, Universal Coke Oven, C. Otto and F. W. Larmann.

The results obtained by Dr. Otto, Coppée and others, exhibit such decided progress over the past, that it is only a question of time when the coke producers of the United States must fall in line.

The advance in the coke industry will cause an advance in the tar color industry, and will further the growth of the soda industry based on the ammonia process.

If I have succeeded in adequately exhibiting the importance of saving the valuable products at present wasted in our coke industries, I shall have accomplished my purpose.

Until every pound of ammonia used in our land is produced in our land, until every pound of soda is made from our own salt wells by the ammonia process, we will continue to be dependent upon the chemical markets of Liverpool and London.

THE FESTNER-HOFFMAN COKE OVEN.

The general design of the Festner-Hoffman coke oven is to simplify construction and operation in the manufacture of coke and saving of by-products.

The *recuperative* compartments of this oven are somewhat simpler than the double regenerators of the Otto oven.

In the treatment of dry coals, it is evident that a high heat with quick application is required in coking such coals; it is also manifest that an efficient method of heating the air, for mixture with the returned gas, is absolutely necessary. But these recuperators and regenerators should be designed in as simple and inexpensive a manner as possible, consistent with efficiency in performing this part of the work in coking.

The Festner oven has the advantage of direct and continuous work, removing the necessity of reversing the air and gas currents, as in the Otto oven, thus avoiding the risk of explosions.

The most important improvement appears in the horizontal posture of the side flues in this oven. In practical operations it has been made very plain that the oven heat, from the combustion of the returned gas, can be regulated much more readily in ovens having horizontal flues, than in those using the vertical posture.

The danger in the latter arises from the tendency to the concentration of excessive heat at certain localities in the oven flues, destroying the fire brick conduits and lining.

From the study of this oven, it is evident, that in its design, some progress has been made in the right direction, in reducing its cost of construction and expense of operation.

It is further manifest that additional study along these lines would be helpful in the introduction of these retort coke ovens in the United States.

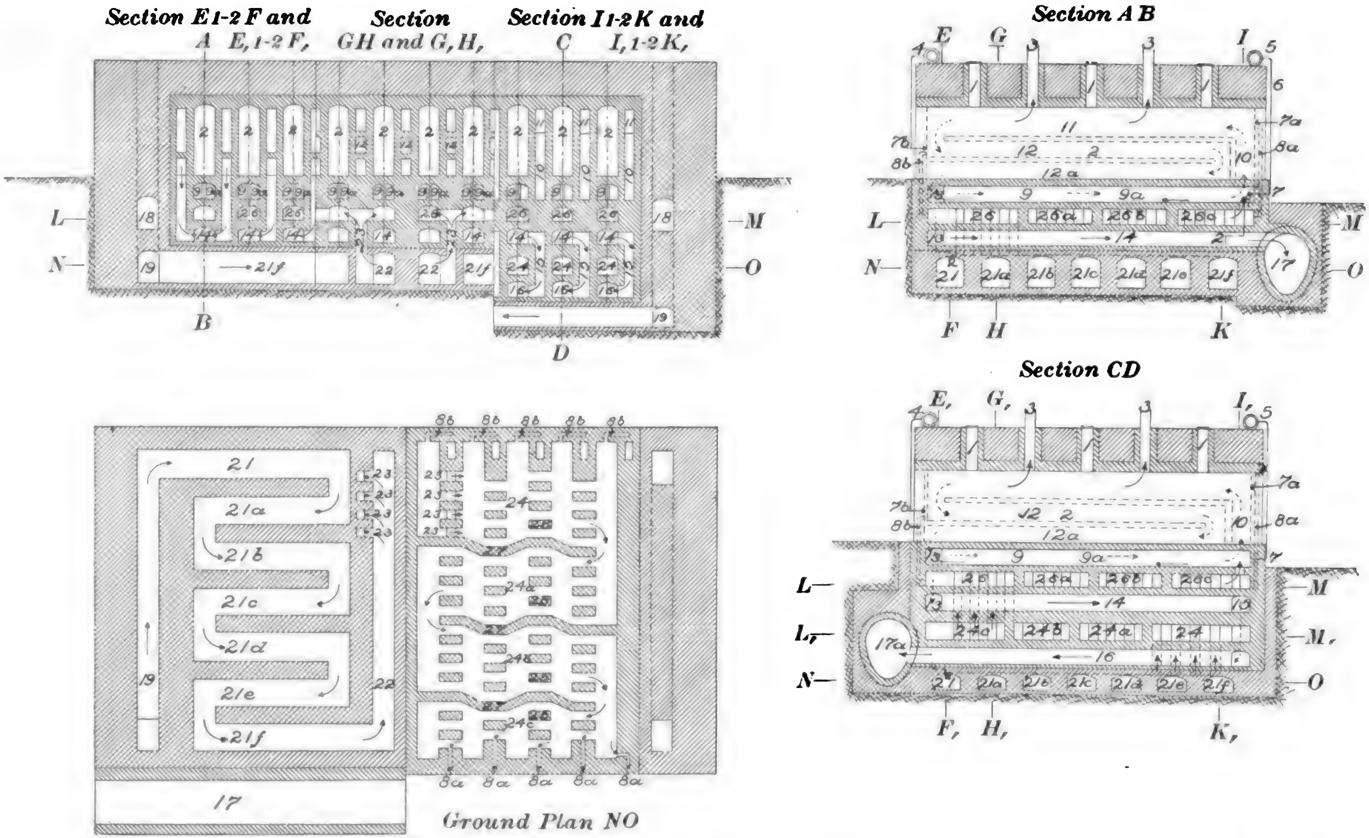


FIG. 61.—THE FESTNER-HOFFMAN COKE OVEN WITH THE SAVING BY-PRODUCTS AND CONTINUOUS AIR HEATING APPARATUS. SCALE 1–200.

Mr. E. Festner* describes this oven as follows:

The well known Otto-Hoffman oven is called the *regenerative* oven; in distinction to this I will call my Festner-Hoffman oven, the recuperative oven (referring to the similarly constructed Ponsard gas furnace), the purpose of which is to dispense with the continual reversing of the regenerative ovens and to effect a permanent heating of the air necessary for combustion. In this work I was assisted by coke inspector Hoffman, a very able engineer, and the father of the Otto-Hoffman ovens.

During long experience with the coking process, I have always found the horizontal flues and the somewhat strong side walled ovens better than the Coppée ovens with vertical flues.

The former can be worked at a higher heat and can be examined, particularly in the flues, more readily; therefore, I equipped my ovens last year with horizontal draughts, similar to the Simon-Carvés system, which is used to great advantage at Bulmke, near Gelsenkirchen.

In building this new plant I arranged, as their advantages are evident, my appliances for the saving of by-products.

As the quality of the dry coal used required a very high heat, it became necessary to heat the air for combustion as highly as possible, and as grave defects appeared in the reversing process, the recuperative oven was suggested more from necessity than inclination.

In explanation I will say, that I call the chamber, where the coal is placed for coking, and the side of oven where the coke pusher operates, the front side, and the other, where the coke is discharged and cooled, the rear side.

The chamber of this oven is 29½ feet long, 23 inches wide and 5 feet 11 inches high. The oven contains, when full, 6½ tons of washed coal for a 48-hours charge.

The chamber walls are 6 inches thick, and the flue walls about the same thickness.

The ovens are combined in groups of 30 each. The hot and air flues, lying under ground, consist of two systems for a battery of 30 ovens.

The accompanying drawings represent, in a comprehensive manner, the general arrangements of these ovens. See Fig. 61.

The chamber is filled with coal through the three charging ports 1. The gas is conveyed through the flues 3, into the condensing apparatus. The exhausted gases return through the pipes 4 and 5, and are sent by the hot air current, which enters at 8, 8 *a* and 8 *b*, through the dividing pipes 7, 7 *a*, on the front and 7 *b*, on the back.

The gases are first led forward and back in the hot flues 9 and 9 *a*, under the oven bottom, they then rise in the vertical hot flue 10, on the rear side, passing through the horizontal flue 11, to the front side; they then go back-

* E. Festner, Director, Silesia Coal and Coke Works, in a paper read before the German Mining Engineers, Sept. 5, 1892.

wards in 12, and forward again in 12 *a*, falling through 13, to the lowest horizontal hot flue 14, in order to reach the central flue 17, which leads the gas under the boilers.

After the heating they receive in passing through these two levels, the gases are led through 15, 16 and 17 *a*.

The air to be heated enters from the outside at 18, falls to the horizontal air canal 19, through the flue system 21, 21 *a*, 21 *b*, 21 *c*, 21 *d*, 21 *e* and 21 *f* (as seen in drawing) and is easily warmed in this system by means of the hot flue 14.

From here the air is led through the horizontal air flue 22 to the vertical flues 23, in order to get to the main system 24, 24 *a*, 24 *b*, and also to 26, 26 *a*, 26 *b*, 26 *c*, from whence it is led as hot air through the vertical draughts 8, 8 *a* and 8 *b*, to be used in the combustion.

The heating, which the air in the flue system undergoes through continually impinging against the small piles, 25, etc., is excellent and the heat of combustion rises 9,000° Celsius.

In the latter described arrangement is the characteristic of our oven, for which Hoffman and I have applied for a patent.

According to the results in question, from this new oven in Gottesburg, nothing remains to be desired; they can be heated very high, are easily regulated, and are, according to experiments which I made with similar ones built by me in Hermsdorf, almost indestructible, so that these new ovens can be recommended as the best.

The waste gas from flue 17 supplies 5 boilers of 45 horse power. With this heat, the boilers not only supply the necessary steam for the condensing apparatus, but power for electric lighting of the whole works as well as for running various small machines.

In order to have as small a depression as possible in the hot flue, a ventilator plant is necessary, which, as in the Otto-Hoffman oven, helps to regulate the supply of air and leads to a uniform heating of the hot flue.

The slight depression in the hot flue stops the gas in the chamber from passing through the cracks in the walls directly into the hot flue and thereby being lost to condensation.

The cost of the oven proper, from the excavation to the time of firing the oven, is estimated (in Germany) at $935.

The cost of oven and by-product apparatus would therefore be as follows (in Germany):

Oven	$935.00
By-product apparatus	1,600.00
Total	$2,535.00

In the United States the cost would be somewhat more, approaching about $3,000 per oven.

No record is given of the work of this oven, but it is fair to estimate its coke and by-products about the same as the Otto-Hoffman oven, a charge

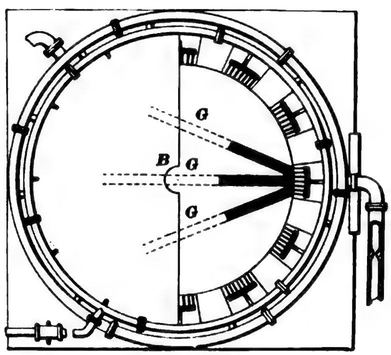
of 6.889 net tons of dry coal every 48 hours giving 5.166 net tons of coke every two days, or 2.583 net tons daily.

The coal used is given as an average of its quality in the district referred to in the foregoing article.

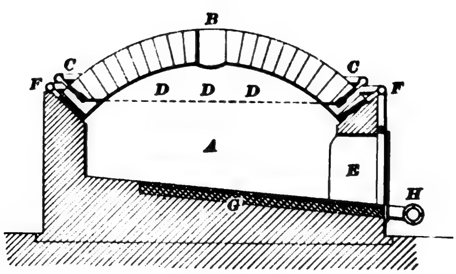
Moisture	0.74	per cent.
Carbon	84.29	"
Hydrogen	4.61	"
Nitrogen	1.62	"
Oxygen	4.77	"
Ash	3.97	"
Total	100.	"

It will thus be seen that the volatile combustible matters amount to 11 per cent., but it is added that usually their average is 20 to 25 per cent.

Mr. Henry Aitken, of Dorrach, near Falkirk, Scotland, has given considerable study to improvements in the Bee-Hive coke ovens during the past fifteen years. The main effort appears to have been given to supplementary appliances to this oven, leaving its normal plan undisturbed.



(a)



(b)

FIG. 62.

In addition to the improvements in the Bee-Hive oven, especially in the efforts to utilize the by-products, Mr. Aitken has originated a design of oven approaching the usual types of narrow retort ovens, but operated on principles differing from those of the narrow ovens generally.

He intensifies the heat of the products of combustion in the upper portion of the oven chamber by mixing sufficient air to assure complete combustion of the gases. Evidently this strong heat with a downward draft to the flue in bottom of the oven prevents the deposit of carbon from the gases evolved in coking.

In a paper read before the Mining Institute of Scotland, Mr. Aitken submitted his improvements, as follows:

In this paper the writer will endeavor to be as concise as possible, and will avoid entirely the history of the subject, and also all detail of the various plans which he has tried; as, although the birth of a new idea may occupy little time, the experimenting takes long, and it takes still longer to convince others that the process is worthy of adoption. The subject will be divided into three heads, viz.:

1st. The making of coke in order to obtain the highest yield and the best quality of coke, at the same time securing the ammonia, oil, gas and heat.

2d. The making of coke in order to get oil and ammonia with a large yield of gas and a smaller yield of coke, and that not of the best quality.

3d. The making of gas to be used in raising steam and in heating or puddling furnaces, and obtaining at the same time oil, or tar, ammonia, but no coke.

First.—The Making of Coke in Order to Get the Highest Yield and Quality of Coke, at the Same Time Securing Ammonia, Oil, Gas and Heat.

Figure 62 shows a Bee-Hive oven, altered to the system which the writer considers to be the best possible where the above objects are desired. In order to carry on the coking in this oven, while at the same time taking off the oils and ammoniacal water, three flues, about four inches square, *G G G*, are made in the bottom of the oven, and these are covered with tiles having perforations about ¼ inch diameter on the top, and one inch diameter on the under side; or bars of iron, wedge shape, with spaces between, may be used as covers. These three flues meet in one near the door, and into this flue the pipe *H* is inserted, which is connected to the condensers, washers and absorbers. These may be of any shape, such as those used at gas and oil works, but it is necessary that a mechanical exhauster or steam jet should be in connection with them in order to assist in drawing the gases from the oven.

The oven is worked in the following manner: The oven having been filled with coal is kindled, and the blast is applied through the pipe *C*; and after a considerable heat has been raised (which generally takes from two to three hours), the top exit from the oven is partly closed, so as to bring a pressure of about two-tenths of an inch onto the gases in the top portion of the oven. The connection to the condensers is then opened, so as to take

off the gas from the flues before mentioned. The exhauster is put into operation, and brings a partial exhaust onto the bottom of the oven of a little over two-tenths of an inch of water; and this state of matters is continued until the oven has worked itself off.

The gases, after being condensed, are deprived of their ammonia and oil, and are forced into the top portion of the oven, through the pipe *F*, where they meet the air from the pipe *C*, and produce a very intense heat, coking the coal with great rapidity. In the Slamannan district the usual time required for coking a 3 ton 10 cwt. to 3 ton 15 cwt. charge of coal is about three days. By adopting the above process the time occupied, using the same coal, is from 38 to 43 hours, so that by this process each oven cokes nearly twice as much coal as the ordinary Bee-Hive oven.

The yield of oil obtained in this way of working was over twelve gallons per ton of coal; sp. gr. from .925 to 1.000; but the yield of oil depends on the kind of coal used. The exact composition of this oil has not yet been determined. It has been purified and made into burning oil, lubricating oil, and paraffine scale. The burning and lubricating oils are not of first-rate quality, and cannot compete with shale oils. The paraffine scale, however, is of good quality, having a high melting point.

The most suitable purpose to which these oils can be applied is the making of gas, when it is desired to increase the illuminating power; but when fractionated the lighter portions can be used for burning in torch lamps, and the heavier for creosoting timber. The loss in distillation is very small, as low as 1 per cent. No doubt if all the coke required in the country were made in this way the market for these articles would soon be glutted; but there is another purpose for which they are well suited, that is, raising steam; and the writer ventures to predict that it will not be long before some of the ocean steamers of this country get their heat from oil. When we consider that the average of our coal produces 14,000 units of heat, and that such oil as this contains about 28,000 units, we can easily see how such a material will come to be preferred to coal, especially as the labor of stoking would also be saved. No fireman to keep on board ship; greater rapidity filling bunkers; one-fourth less space required for the storage of a ton of oil compared with a ton of coal; these are important points; besides, every ton of oil will raise more steam than two tons of coal, for the heat units in the oil are twice what are in coal. But this does not represent the full advantage that will be got, as the supply of oil could be perfectly regulated, and the gases consumed, which cannot well be done in coal firing.

As regards the yield of ammonia there are no figures to show; but as the oven was formerly worked by allowing about one-half of the gases to ascend direct to the top of the oven, and be there burned, only taking down about one-half of them, and in this way of working a quantity equal to 5½ lbs. sulphate per ton of coal was got, and that, too, without scrubbing or

washing the gases; there are grounds for the confident belief that between 20 and 25 lbs. of sulphate per ton of coal was got from coal containing the usual 1½ per cent. of nitrogen that is found in most Scotch coals. An eminent chemist, who had just concluded a series of experiments to ascertain the amount of ammonia in certain coals, informed the writer that if the gases from an ordinary retort were allowed to pass away from the condenser pipe without being scrubbed, they would carry away as nearly as possible one-half of the ammonia with them.

The yield of coke is 1 or 2 per cent. less than that got from a retort. It may be here remarked that the yield of coke from ordinary Bee-Hive ovens at Slamannan is from 50 to 52 per cent., while by this process 65 per cent. was got, showing a difference of 25 per cent. of coke in favor of this process. The quality of coke made was of the finest, and very much superior to that manufactured in the ordinary way.

There is ample heat in the gases, after they leave the ovens, to raise all the steam required for the blower and exhauster; and a portion of the gases could be spared and consumed for other purposes. The illuminating power of the gases is not great. It was not tested with a photometer, but the appearance of the flame, which varied according to the state of the oven, indicated from 6 to 12 candles. Almost any kind of oven can be altered to this system.

The profit and loss of this process may be stated thus: Say 10,000 tons of coal are coked, and presume that one oven by the new process will do as much work as two of the ordinary Bee-Hive ovens, and that the additional cost of blower, exhauster, condensers, etc. (so far as estimates have been made, the costs seem equal), for each oven in the new process is the same as the cost of an ordinary coke oven, so that the capital expended for the amount of coal coked is the same in both cases. The old process gives a yield of 52 per cent. of coke: 10,000 tons coal = 5,200 tons coke.

By this process 10,000 tons coal will give, at 65 per cent., 6,500 tons coke; difference of 1,300 tons coke at, say 10s	£650
12 gallons oil per ton, 120,000, say at 1d. per gallon	500
Say only 12 lbs. sulphate of ammonia per ton, at 1d. per lb. profit	500
	£1,650

Four men should be able to attend to the blower and exhausters, and the regulating of 50 ovens. These 50 ovens should make into coke 10,000 tons coal in 125 days; so that there falls to be deducted from this £1650 a sum of from £80 to £100 for wages; and, say £10 for oil and furnishings for engine.

The coke made by this process is of much better quality than that made in the ordinary Bee-Hive oven, but there is not anything added on that account, although it would be quite justifiable to do so. It is of advantage in making coke in any kind of oven, when coals are of a very dry or non-

coking or gendering description, to mix pitch or tar with them before they are put into the oven, and among the samples produced is some of the coke so made in the oven described.

Secondly. — THE MAKING OF COKE IN ORDER TO GET OIL AND AMMONIA WITH A LARGE YIELD OF GAS, HAVING THEREBY A SMALLER YIELD OF COKE, AND THAT NOT OF THE BEST QUALITY.

Figure 63 shows an apparatus for accomplishing this. The chamber *A* is partly filled with coal and kindled on the top. So soon as it has kindled all over, air is forced in through the pipes *Z*, and the products of combus-

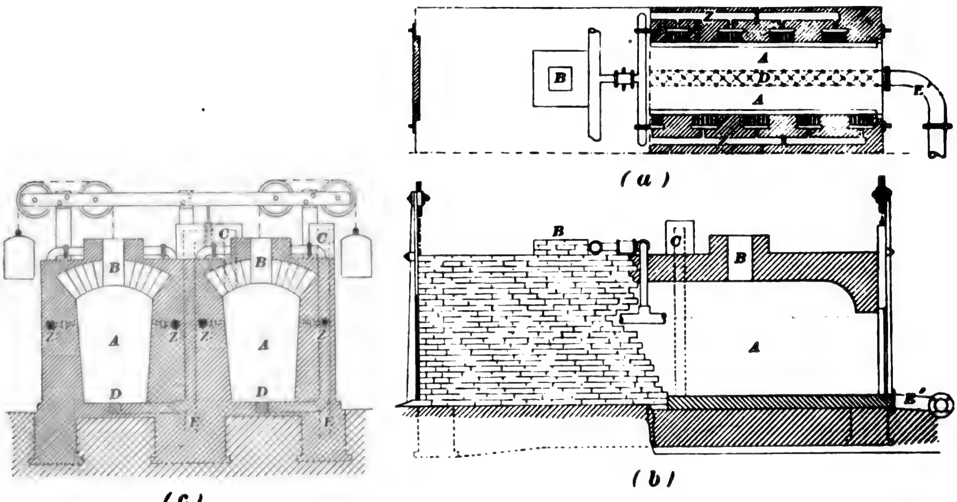


FIG. 63

tion and distillation are forced down through the coal into the flue *D*, which is covered with perforated bricks, or iron bars set apart. The gases are carried off by the pipe *E*, which connects with condensers, scrubbers, and absorbers—the gas being freed from its ammonia by water, and the hydrocarbons being absorbed by passing the gas through cold tar. So soon as all the volatile matter is drawn out, the air is shut off and the coke drawn, or watered out and drawn.

The yield of coke got in this manner of working is from 40 to 48 per cent. from coal giving in a retort 60 per cent.; the quality not first-rate, but good enough for smithy purposes and for use in blast furnaces of moderate height. The quality of the coke depends of course very much on the kind of coal used. The apparatus with which the trials of this process were made was only provided with a condenser, and without washer or absorber; so that neither the full amount of oil nor ammonia was got, but the yield of both was good, considering these circumstances, viz.: about forty gallons water per ton giving equal to 16 lbs. of sulphate of ammonia, and twelve gallons oil per ton of coal. If the same rule is applied, to which reference

is made in the previous part of this paper, the amount of ammonia to be got in this manner of working will be over 30 lbs. of sulphate per ton of dross or small coal. The analysis of this oil is as follows:

SAMPLE OIL.

1st.—1.43 per cent. distilled of specific gravity, .876 at 60° Fah.
Do. re-distilled B. P. 130° C.
Yields ½ per cent. at 140° C.
5 per cent. at 150° C.
20 per cent. at 160° C.
160° C distillate re-distilled = 0.286 per cent. of original quantity sp. gr. .812 at 60° Fah.
B. P. 100° C.
Yields 10 per cent. at 120° C.
30 per cent. at 130° C.
65 per cent. at 140° C.
90 per cent. at 160° C.
2nd.—5.72 per cent. sp. gr. .900 re-distilled B. P. 162° C., 10 per cent. 180° C.
3rd.—15.00 per cent. sp. gr. .934.
4th.—15.00 per cent. sp. gr. .948.
5th.— 8.00 per cent. sp. gr. .955 containing about 3 per cent. paraffine scale.

45.15
54.85 Coke and loss.

100.00.

The examination of this oil proves that it belongs to the series between paraffine crude shale oil and coal tar. The only product in it that is identical with a product derived from either of the others is the paraffine scale; but as the latter is found in minute quantities in many Scotch coal tars, there is nothing out of the way in this further than that it is present in a larger proportion. A portion of the 0.286 distillate refined is produced. It is exactly the sp. gr. of No. 1 paraffine oil, but is of a different nature altogether, being too volatile. If it were .862 sp. gr. in place of .812 and the same volatility, it would consist of a mixture of toluole and solvent naphtha. It dissolves india-rubber and gutta-percha with great rapidity.

Nos. 2, 3, and 4 distillates might be used for creosoting wood. The sp. gr. of these is too high and the body too thin, with smell too strong to make good lubricating oils to compete with shale crude oils.

The fifth 8 per cent., after extraction of paraffin scale, might make an indifferent grease oil. These oils, 2, 3, and 4, are worth 2d. per gallon, and if 6 per cent. of oil is left in the pitch, it is worth 25 shillings per ton.

The amount of gas got was not measured, but it is estimated to amount per ton of coal to 7,000 feet hydro-carbon gases and 12,000 feet carbonic oxide gas. When it is desired to make the liquid hydro-carbon products of a tarry nature, one charge of coal is coked, and when the coke is still hot, another charge of coal is put on the top, and the process

is carried on as before. This may be repeated as often as desired till the chamber is full. When it is desired to produce hydro-carbon oils as near as possible to the oil-work series, there is forced in with the air on the top a certain quantity of steam or water, and by this means more ammonia is got; and if it is wished to produce even better results in this direction, the products of one oven are drawn or forced through the flue *C*, as shown in dotted lines on plan, Fig. 63 (*c*), and down through the coal in another oven.

Thirdly.—The Making of Gas to be used in Raising Steam, and in Heating or Puddling Furnaces, and Obtaining at the same time Oil, or Tar, Ammonia, and no Coke.

The first apparatus to which reference will be made, is the same as that last described and shown on figures *a*, *b*, and *c* Fig. 63—the only difference being that the flue *D* is covered with iron bars with spaces between them; and it is made larger so as to admit of being more easily cleaned out. The process is carried on in the same way as last mentioned, with this difference, that the air is applied till all the coke is consumed, steam also being put in with the air. The gases are condensed and treated as in the other process. So soon as the coke is nearly all consumed, the air is shut off and the ash withdrawn, and the chamber refilled with coal. The oils got in this manner of working are much the same as those obtained by the last mentioned method of working. The ammonia should be considerably increased, but this has not been determined.

In the manner of working, the whole top surface of the coal is exposed to the air, and so the combustion is slow. No clinker was formed with any of the coals tried. The steam added also prevents the formation of clinker when it is desired to carry on the making of gas without interruption for cleaning. Flues are put between the producers to carry the products of combustion over, or to the top of the coal in the next producer; and so soon as the coal is nearly all consumed in the first chamber, these flues are opened and the gas passed through the material in the next producer. The air is applied till all the carbonaceous matter is consumed in the first producer, when it is put directly onto the second producer, and so on. In this manner of working, gas is produced continuously. Many have objected to the system of making gas in a separate chamber from that in which it is to be consumed. They allege that the loss of heat is great in respect that the heat developed in making the carbonic oxide is lost; and the heat units developed in making carbonic oxide amount to 4,452 out of a total of 14,544 heat units when the carbon is all reduced to carbonic acid. But these gentlemen forget that the 4,452 units of heat developed in making carbonic oxide are the heat units from dry carbon, and not the heat units developed in making carbonic oxide

from common coal. The writer has not been able to ascertain how many heat units will be developed in making coal into carbonic oxide; and it will not be an easy matter to arrive at this: no doubt they will vary with the different kinds of coal. From experiments it is perfectly clear that the greater portion of the heat is utilized in distilling the coal and driving out the hydro-carbons and water.

Others have objected to the use of gases from which hydro-carbons have been partly taken, on the ground that the loss of these would reduce the heating power of the gases to a very great extent; but these gentlemen have failed to keep in mind that if so much of the hydro-carbons are taken away, so too is the aqueous vapor; and as all the hydro-carbons taken out only amount to, say, 12 gallons, or 120 lbs., and the aqueous vapor amounts in many cases to 336 lbs. per ton of coal, it is quite clear that these dried gases will burn better and do more work, and that in a shorter time than the aqueous-burdened gases. This has been the writer's experience, and it is now the experience of others.

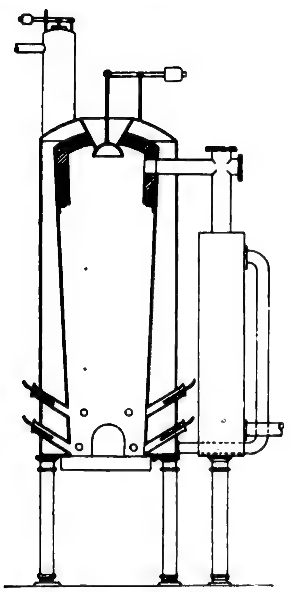


Fig. 64.

In order to meet the objection to the loss of heat in making carbonic oxide, and trouble with clinker in the producer, the Boiler Producer, Fig. 64, was designed. Here the initial heat is absorbed by the boiler; and any heat in the escaping gases is taken up by the feed water for the boiler passing through a series of pipes placed in the "downcomer," on the right of Fig. 64. By this means little heat will be lost. The plan shows that the bottom of the apparatus is hinged, to admit of the ash being easily taken out. In this arrangement the air is forced in by steam jet, the bottom jets being used first; and as they get closed with ash, the upper range of jets is applied.

In many works it is desired to continue the making of gas without stopping for cleaning. In such cases a brick building is put below the boiler, using a blower, and fluxing the ash with lime, etc., and running it out at the bottom as slag. In this case steam is added above the tuyeres. The object of adding steam is to secure more ammonia. The point at which the steam should be introduced will be regulated by the speed at which the producer is driven.

The tars, or oils, and ammonia got in this upward system of distillation are very much the same as those got from blast-furnaces, so far as the writer's tests have gone; and, indeed, they should be the same, as the circumstances under which they are produced are very much alike.

Many coals gender and coke in gas producers, and so cause the producer to work irregularly; besides, the coke so made is close, and the air does not get through it with sufficient rapidity. In order to put both these points right, mechanical stirrers are introduced into the top portion of the producer, and steam or water is passed through them to keep them cool.

ELLIPTICAL BEE-HIVE OVEN.

This is simply an application of the Bee-Hive coke oven, for saving by-products. Bottom flues are added, with passages for the utilization of the gases evolved in coking, which can be carried under boilers or condensed for the saving of the by-products of tar and ammonia.

In coking a dry coal, or coal low in volatile matter, some additional heat would be afforded from the bottom flues, as this portion of the oven is sensitive to the want of heat afforded in coking this quality of coal. It is especially felt if the coke is watered in the oven, which is the usual method in this type of coke oven.

In some cases a double bottom is placed in Bee-Hive ovens to store heat in coking the several types of coals low in volatile matter.

It is becoming evident, however, that the narrow retort class of coke ovens affords the best results in the manufacturing of coke from the dry qualities of coking coals.

The large cost of these ovens, with the high patent rights following, have retarded their introduction in a large measure.

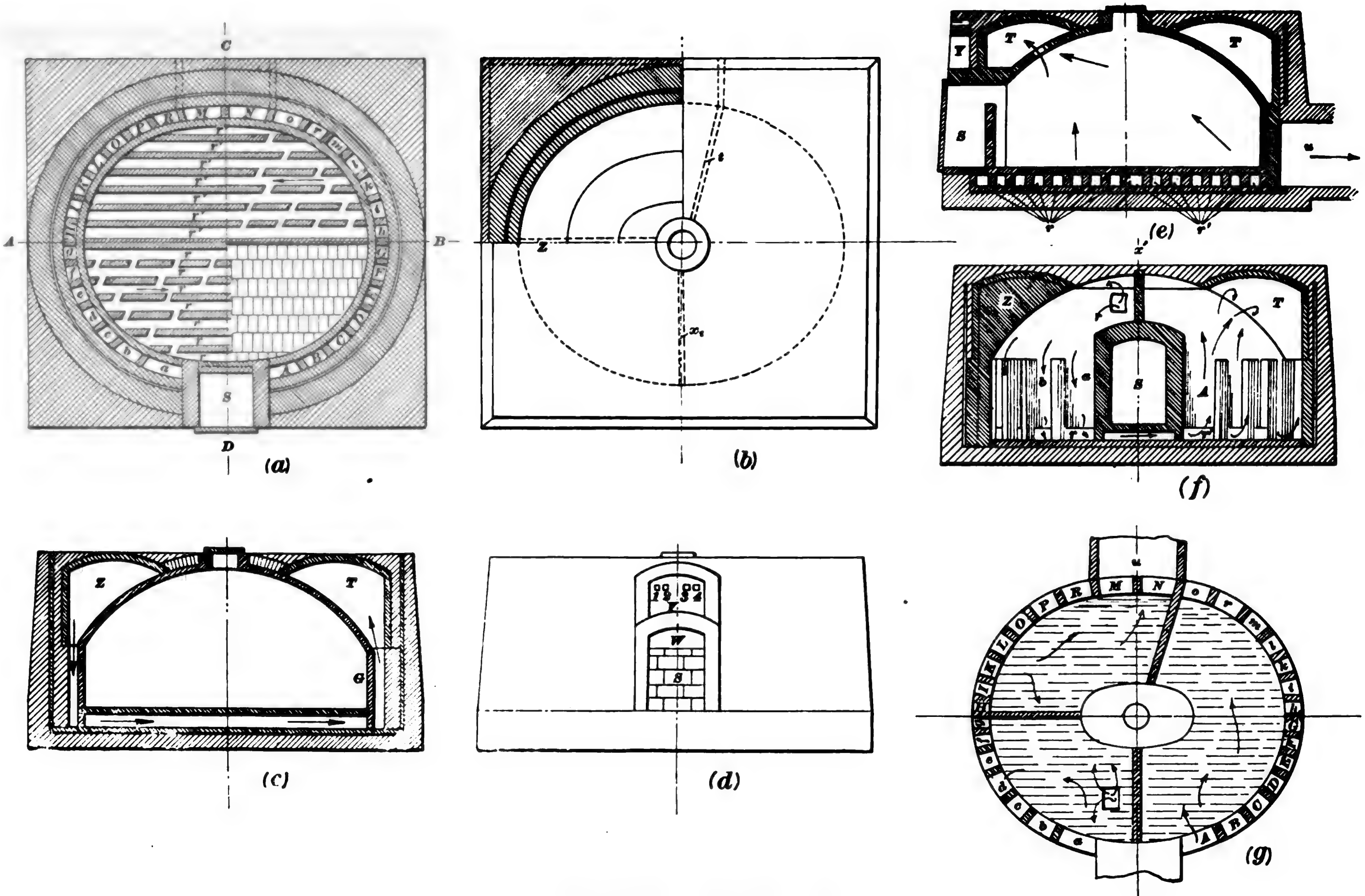


FIG. 65.—ELLIPTICAL BEE-HIVE OVEN.

I am indebted to Mr. Walter M. Stein, Metallurgist, of Philadelphia, for the drawings and description of this elliptical Bee-Hive coke oven.

Fig. *a* is a plan of the oven showing the bottom flues and side passages.

Fig. *b* is a view from the top (a part of the vault is taken off).

Fig. *c* is a vertical section in line *A B* of Fig. *a*.

Fig. *d* is an elevation with door.

Fig. *e* is a vertical section in line *C D*.

Fig. *f* is a front view (the outer wall taken away).

Fig. *g* is a top view (the roof taken off).

As shown in Fig. *a*, the space under the sole of the oven is divided by the wall *X*, in the direction of the great axis of the ellipse, in two equally large, not communicating parts, each of which has 7 flues, *r* and *r'*, whose ends communicate with the side passages *a b*, *A B*, etc. Below the sole of the oven there are thus 14 flues of equal width and height, and connected with side passages of varying width, which grow wider as the bottom flues, with which they connect, increase their distance from the great axis of the ellipse. In the intermediate space between the two side passages farthest away from the great axis of the ellipse, and on the front side of the oven, there is sufficient room remaining for the construction of the door *S*, without interrupting the connection between side passages *a A* and the communicating sole flue *r*.

The sections *A B* and *C D* in Figs. *c* and *e* and Figs. *f* and *g* show that over the vault of the oven, adjoining same and covering all the side passages, there extends a vaulted space *T*, all around, to receive through the opening *y*, in the vault of the oven proper, the gases which are generated inside, and to lead them to side passages and sole flues, through which they pass, and to receive them again, prior to leading them to the collecting flue *n*, which is reached through the side passages *M* and *N*.

In order to attain an uninterrupted circulation of the generated gases through the side passages and sole flues, the space *T*, above the vault of the oven proper, is divided into three compartments by walls, thus necessitating the gases to accumulate in these compartments and force them to take their way through the side passages and sole flues in a given direction, rise on the other side and proceed to the passages *M* and *N*. The way taken by the gases in the side passages and sole flues, as well as in the space *T*, is illustrated in Figs. *f* and *g*.

One of the dividing walls *x'* of the space *T* is situated, as Figs. *f* and *g* show, over the middle of the vault of the door in front of the opening *y*, in the vault of the oven proper, and through which the gases reach the space *T*. The second wall *Z* (Figs. *b*, *e* and *g*), is between the side passages *g* and *H*. The third wall *t*, lies back of the side passage *o* and before *N*, which leads to *u*.

(*A*) The way taken by the gases is indicated by arrows, and is as follows: The gases enter the space *T* from the inside of the oven through the

opening y, and find their way barred by the wall z; they accumulate between the walls x x' and are forced to take their way through the side passages $a, b, c \dots g$; from these they reach, by means of the bottom flues r, the side passages $A, B, C \dots G$, and through the latter the second compartment of the space T. The wall t again barring their way, the pressure resulting from their accumulation forces them to take their way through the side passages $h, i, j \dots o$, reaching the bottom flues r', and by means of these the side passages $H, I, J \dots R$. Rising in the latter they reach the third and last compartment of the space T where the wall t again forces them to fall through the side passages M and N to flue u, from which they proceed either to the chimney, boiler or condensing plant (B).

THE SEMET-SOLVAY COKE OVEN.

The Semet-Solvay retort coke oven came into appreciative notice in Europe, in 1887.

This oven was evidently designed to secure three chief elements in the coking of coal and saving its by-products.

First. To coke "dry" coals, such as inherit only 15 to 17 per cent. of volatile combustible matter. This is secured by the quickly applied heat during the initial operation of coking, thus obtaining the full benefit of the fusing matters in the coal and producing the hardest bodied coke possible with such quality of coal.

Second. To store heat in the oven walls, to be made available in starting the coking operation, after a fresh charge of coal has been placed in the oven; avoiding the expensive auxiliary arrangements of "regenerators" or "recuperators."

Third. To secure in a direct and simple manner the by-products of tar and ammonia in coking, enhancing the profit of the coke manufacturer.

An examination of the accompanying plans and sections of this coke oven will show the general scope of its design. See Fig. 66.

The oven chamber is usually 30 feet long, 1 foot 4½ inches wide and 5 feet 6 inches high.

These dimensions are subject to be increased or diminished to meet the requirements of coking each quality of coal.

Its side walls are faced with flued and jointed tiles in horizontal posture, which affords the best condition for the regulation of the heat and its proper distribution, so as to avoid its destructive concentration at any part of the oven.

These flued tiles are quite thin, quickly transmitting the heat from the combustion of the returned gases to the charge of coal. This heat is sustained by drawing on the heat stored between the flued lining of the ovens a, in the dividing walls.

This stored heat is maintained by the return of the surplus heat towards the close of the coking of each charge, and is ready to be used in supple-

menting the heat of ovens on the introduction of each fresh charge of coal, avoiding the chilling of the fusing matter in the coal by a slow process of coking.

In this oven the massive arch and covering *d*, afford a very important second heat storage reservoir for each oven, which insures the maximum heat at the upper portion of the charge of coking coal.

These two repositories for heat storage *a*, *b*, obviate the necessity of auxiliary appliances for heating the air for combustion of the gases, which are essential in other systems.

The oven is also capable of coking the richer or pitchy coals, but its chief merit consists in its successful treatment of coals, low in hydrogenous matters, that are difficult to coke in ordinary ovens.

It, therefore, measurably anticipates a time when the chief sources of the best coking coals shall have been reduced in extent, and when the coke manufacturer will be compelled to fall back on the less valuable or "dry" coking coals to maintain the coke supply.

The design for an oven to coke the rich or pitchy coals will, in time, engage the attention of oven builders, reversing the heat conditions of the Semet-Solvay oven, to produce coke without the usual inflated cellular structure now barring the use of such coals for the manufacture of metallurgical coke.

It may be noted that the Semet-Solvay ovens afford sufficient surplus heat to make steam in boilers, located near the ovens, for all purposes of all the operations of the manufacture of coke and saving of the by-products.

Mr. E. Festner, Director of the Selician Coal Works, Gottesburg, reports that a Semet-Solvay oven will coke 1,440 tons of coal, producing 1,125 tons of coke per year.

About 78 per cent. of coke is obtained from the coal charged; all 24 hours coke.

He further gives the cost of this oven in Europe and its appliances, as follows:

Cost of oven complete	$1,168.75
Apparatus for saving by-products	1,402.50
Boiler plant, heated with gas	490.87
Storage bin and coal mixer	420.75
Total cost per oven	$3,482.87

In the United States the cost per oven, of such a plant, would exceed the above.

It has been suggested that the use of silica material in the flued tiles, in the oven lining, would add to their permanence in performing their important functions in the oven, and reduce expenses of repairs.

A plant of 12 Semet-Solvay retort coke ovens is now in operation at the works of the Solvay Process Company, near Syracuse, New York.

This plant has been constructed in a very perfect and substantial manner, with improved appliances for extracting and saving the by-products of tar and ammonia.

It is designed at some future time to add 12 more ovens to the present plant, making in all 24 ovens.

The exhauster and apparatus for securing the by-products are sufficiently large to take care of the products of 24 ovens or more.

The main design is to obtain coke as free as possible from sulphur, and and at the same time secure the by-products of tar and ammonia.

The plan of this oven is shown in the accompanying drawings, which have been kindly furnished by W. B. Coggswell, Esq., general manager of the Solvay Process Co. of Syracuse. The cost of this plant is as follows:

Ammonia Concentrator	$ 1,584.74
Boilers	10,210.56
Coal Trestle	3,039.58
Coal house plant	5,027.23
Chimneys	3,107.93
Pusher	3,112.46
Producer	701.00
Ovens (12)	28,685.30
By-product Building	7,365.74
Washers (2)	2,856.69
Exhauster (2)	2,511.16
Shafting	841.47
Hydraulic mains (2)	2,281.84
Gas Condenser (4)	6,521.42
Piping and other Contingencies	10,167.32
Total	$88,014.44

From this it will be seen that the ovens cost $2,390.45 each. The ovens with the appliances and pusher will cost $7,334.53 each. Increasing this plant to 24 ovens, and estimating the cost of the 12 additional ovens at $2,000 each, the aggregate cost of the plant will be $112,014.44. The average cost of the ovens is $2,195.23 each.

The average cost for by-product saving apparatus, would be $2,472.04 for each oven.

It is quite probable that with a still further increase of ovens the average cost of ovens and by-product appliances would be much reduced.

The coal used in these ovens is small or fine coal, and is procured from the Morris Run Coal Company, Tioga Co., Pa.

It is constituted as follows:

Moisture	0.160
Volatile Matters	19.120
Fixed Carbon	70.780
Ash	8.910
Sulphur	0.7318

The theoretic coke in the above coal is 80.12 per cent.

During the month of June, 1,656½ net tons of coal were used in the 12 coke ovens, producing 1,273½ net tons of large coke and 46½ tons of "breeze," exhibiting a total product of 1,320 tons of coke and "breeze."

The total product of coke is 79.68½ per cent. of the coal charged into ovens; of this 2.80 per cent. is "breeze" or small coke, leaving of marketable coke 76.87½ per cent.

As the theoretic coke from this coal is 80.12 per cent., it is evident that very little waste of fixed carbon has been made in coking. On the other side it appears that very little carbon has been deposited from the volatile hydro-carbons in coking. This is further confirmed by the absence of the bright silver glaze which evidences this deposit on coke.

The daily charge for each oven is 4.6 net tons of coal.

The coke and "breeze" produced, 3.67 net tons.

One oven produces 106.12 net tons of marketable coke per month or 1,273.44 net tons per year.

The by-products of tar and sulphate of ammonia, made during the month of June, are as follows:

Tar	43.6 lbs. per ton of coal.
Sulphate of Ammonia	9.88 lbs. per ton of coal.

The revised cost of labor in making coke and saving by-products is given at $1.08 per net ton. It is estimated that with a 24 oven plant, this cost would not greatly exceed 60 cents per net ton of coke made and by-products saved.

The value of the by-products, per ton of coke made, is placed at 48 cts.

These ovens are run continuously with three shifts of men, making the cost of the work somewhat above other types of ovens.

With the dry quality of coking coal used in these ovens, inheriting only 17 to 19 per cent. of volatile combustible matters, it is evident that the results of the retort coke ovens clearly indicate that this is the best oven for coking this rather inferior coal. The percentage of coke made (76.87½), with its hardness of body and its consequent condition to resist dissolution in its passage down a blast furnace, by the action of the ascending gases, gives it additional commendation in producing metallurgical coke.

A similar quality of coal, coked in the Bee-Hive oven, afforded only 61 per cent. of coke rather softer in body than the retort coke, and consequently less valuable as a fuel in metallurgical operations.

When the several types of coke ovens shall have been considered, with cost of plant, expenses of operating and physical properties of their products of coke compared, a general review of the merits and demerits of each kind of oven will be submitted.

At this time it can only be pointed out, that such an analysis of coking will embrace two lines of determinations: 1st. Whether metallurgical coke is the prime requirement, with or without by-products as a secondary mat-

ter; and 2d, When the by-products are the chief product, with coke only a secondary interest.

With the largely increased cost of a coking plant for saving by-products, and its increased cost in labor above the coke plants without the saving of by-products, it becomes a serious consideration whether the market value of the by-products will secure increased profits to cover increased investment in plant and extra labor expenses to the coke manufacturer.

In a recent communication (July 10, 1894), F. R. Hazard, Esq., treasurer of the Solvay Process Co., of Syracuse, N. Y., states:

"In the matter of the present results of the block of Semet-Solvay ovens, in Syracuse, we would say that, running on Morris Run coal, the percentage of marketable coke to coal used was 78.2%. In addition to the coke there is from 2 to 3% of breeze. The by-products amount to 42¼ pounds of tar per ton of coke, and 16.12 pounds of sulphate of ammonia per net ton of coke. We will be obliged if you will make this correction in the revision of your articles.

"We cannot use our small block of 12 ovens for a fair criterion of either original or operating cost. By the European practice, the cost of a Semet-Solvay oven is $1,000 against $1,200 for an Otto-Hoffmann oven; and the Semet-Solvay oven will produce double the quantity of coke, requiring but 22 hours against 48 hours for the Otto-Hoffmann oven.

"The cost is for the oven only, not the by-products. The cost of operating a block of 25 Semet-Solvay ovens, making 28 charges of 4½ net tons each in 24 hours, equal to 126 net tons of coal producing 101.5 net tons of coke, is two engineers and 20 laborers. At $2.25 per day, per engineer and $1.40 per day for laborers, this would amount to $32.50 operating cost for 101.5 net tons of coke, or 32 cents per net ton of coke.

"One extra man will attend to the by-product works."

Since receiving the foregoing communication, the writer again visited the plant of 12 Semet-Solvay ovens on the large works of the Solvay Process Co. In the absence of Mr. Hazard, Mr. Thomas Morris, superintendent of this coking plant, showed the recent make of coke, which is excellent. It is an improvement of the product I saw about a year ago. The output of these 12 ovens is now 52 net tons per day, or rather per 22 hours, which is remarkable work.

Mr. Morris is an expert in the management of this type of ovens and in directing the condensing operations.

For the large class of "dry" coals, this oven is admirably adapted to produce very good metallurgical coke—as good as can be made from this dry coking coal.

It may be submitted here, as a general principle, that first class coke cannot be made from second class coals.

Twelve Semet-Solvay coke ovens, with apparatus for saving the by-products of tar and ammonia sulphate, have been in operation during the

year 1894, at the large chemical works of the Solvay Process Company, Syracuse, New York.

Mr. W. B. Coggswell, the managing director, has kindly furnished the following statement of the year's products of coke, breeze and by-products. The large output of coke is remarkable, as it greatly exceeds the best record of retort ovens which has come to our notice. From the strikes at the coal mines during the year, the output of coke was reduced owing to the insufficient supply of coal.

Experiments in these ovens, with Connellsville coal, for the Illinois Steel Company, afforded remarkable results in the increased product of coke. It was shown that coke could be made from this coal in 16 hours that in quality was satisfactory to the representative of this company, Mr. Whiting, who remained at ovens during the time of the experiments. This indicates a daily output of coke of nearly 6 tons. During two visits of the writer to these works, very full statements of the work of the ovens were kindly furnished.

COKE OVEN STATEMENT FOR THE YEAR 1894.

Coal and Products.	January.	February.	March.	April.	May.	June.
Morris Run, Pa., tons	1827.6	1873.9	1786.7	1012.9	850.0	786.0
Clearfield, Pa., "	....	....	....	....	....	654.9
Reynoldsville, "	291.6	262.1	....	....	....	....
Pocahontas, "	....	....	....	....	434.8	218.3
Benton, "	137.5	....	....	....	....	....
Phillips, "	....	....	....	818.6	444.1	....
Coal used, total "	1756.7	1636.0	1786.7	1826.5	1728.9	1654.2
Coke large, " "	1374.6	1282.4	1421.5	1454.2	1409.8	1382.6
" " % of coal	78.2	78.4	79.5	79.6	81.3	83.5
Breeze, total tons	62.2	56.4	51.7	41.1	36.9	30.3
" % of coal	3.5	3.4	2.9	2.2	2.13	1.83
Ammonia (Sulphate) lbs	28327	25592	24413	27066	23315	27501
" " per ton coal, lbs.	16.12	15.64	13.66	14.81	13.50	16.62
Tar total, lbs	74240	75310	77440	83540	82050	83500
" per ton coal, lbs	42.2	46.0	43.3	45.7	47.4	50.4

Coal and Products.	July.	August.	September.	October.	November.	December.
Reynoldsville, tons	....	978.3	....	....	....	....
Morris Run, "	....	421.1	1847.2	1900.2	1883.0	1721.7
English Steam, "	139.0	18.8	....	....	....	....
Belgian, "	1698.4	501.9	....	....	....	....
Ind., Ill., & Pa. (sample)	....	....	....	....	....	337.0
Coal used, total tons	1837.4	1910.1	1847.2	1900.2	1883.0	2058.7
Coke, Large, "	1531.8	1543.1	1495.8	1569.7	1537.0	1528.7
" % of coal	83.3	80.78	80.7	82.6	81.6	74 25
Breeze, total tons	83.2	66.32	55.6	64.8	64.3	65.3
" % of coal	4.53	3.47	3.01	3.41	3.41	3.17
Ammonia (Sulphate) lbs	22987	27827	22659	27060	25766	26872
" " per ton coal, lbs.	12.50	14.60	12.20	14.42	13.67	13.05
Tar, total lbs	63750	81800	73060	76960	83740	61840
" per ton coal, lb	34.6	42.8	39.6	40.0	44.4	30.0

COKE OVEN STATEMENT FOR 1894.

SUMMARY.

Coal used, total short tons (2000 lbs.)	21825.6
" per oven. "	1818.8
Coke produced, total short tons	17531.2
" per oven, "	1460.9
Breeze " total "	678.1
" " per oven, "	56.5
Percentage of Large Coke to Coal	80.33
" " Breeze	3.17
" total Coke to Coal	83.50
Ammonia Sulphate, total lbs	309385
" per oven, lbs	25782
" per ton of coal, lbs	14.27
Tar produced, total lbs	917230
" per oven, lbs	76435
" per ton of coal, lbs	42.2

Owing to insufficient supply during the strike the production was limited by the receipts of coal.

THE SLOCUM BY-PRODUCT COKE OVEN.

Dr. F. S. Slocum, President of the Gas Engineering Company, of Pittsburg, Pennsylvania, has recently designed a retort oven for gas producing as well as for the manufacture of coke and the saving of the by-products of tar and ammonia sulphate.

It will readily appear that this oven has been designed to embrace in harmonious relations the most desirable elements in the Hüessener and Semet-Solvay coke ovens. See Fig. 66 *a*.

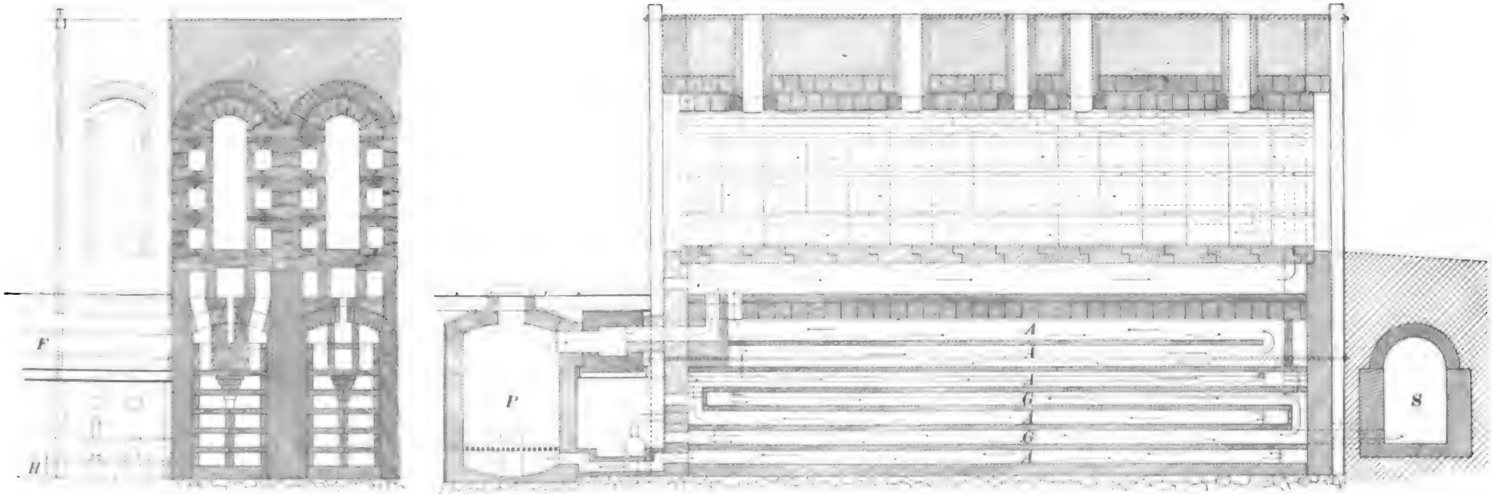


Fig. 66 *a*.—GENERAL PLAN OF SLOCUM FULL DEPTH OVENS.

AAAAA, Air Flues.
GG, Gas "
F, Gas Flue from Producer.
H, Hot Primary Air Flue.
P, Producer.
S, Sewer.

Modern practice is rapidly trending to thin heating walls, with horizontal flues. This assures rapid work in coking, 20 to 24 hours, and consequently a much larger output from the investment in the oven.

The horizontal flues assure direct and readily controlled heat appliance; and afford all needed facilities for cleansing the flues.

The combination of the flue tiles is designed to simplify construction and render renewals easily made without serious interruption to the adjoining ovens.

The quick introduction into a new country of a process, which has been in sucessful operation in other countries for more than a decade, means numerous changes in the general details of such a process, in order to adapt it fully to the wants and requirements, which, out of necessity, must differ from those under which the system has been operated in the mother country. The by-product coke oven, in its present state of perfection in Europe, is divided distinctly into two classes: one which produces blast furnace coke in twenty-four hours, the other producing the same quality of coke in forty-eight hours. In the one which produces coke in twenty-four hours there should be two sets of flues for each oven, while in those ovens which produce forty-eight hour coke there is an oven side-wall on either side of the single flue, the flue, therefore, heating a half of two different ovens at the same time. Admitted that both produce the same quality of coke from the same coal, the demand would be, under the new conditions, (especially in America) for the oven which would give the most coke in the shortest time, viz., the twenty-four hour oven. The great difficulty meet with in this class of oven has been its very expensive and open construction, the side plates opening up at their joints one with the other, by expansion and contraction, so much so that a large percentage of nitrogen is always found in the gas, and the necessary thinness of the walls of these flues makes them very liable to breakage and very hard to replace. The principal difficulty, however, is the first one mentioned—the leakage to and from the flue and oven, and also around the flue into the space between the division-wall and flues. The full depth coke oven, as shown in Fig. 66*a*, is designed to overcome these difficulties. The sides and top of the oven are so constructed that there are no strains upon the brick work when a given change of temperature is experienced inside the oven. The shapes of which the sides and tops are made are very simple in construction, can be readily removed for repairs and have the very great advantage of being exceptionally gas-tight. Further, the width of the oven, and the thickness of the side-walls can be changed at very little expense, and in a very short time. The entire design of the flues, with their division-wall, is such that the greatest control is had of all parts of the construction.

The full depth feature is new. The products of combustion, after leaving the flue, are passed back and forth underneath the oven, and the air for the combustion of the producer gas is passed between these flues in

an opposite direction, and last, the primary air for maintaining the temperature in the producer, with its necessary steam, is superheated by the products of combustion before they leave for the stack. This reduces the temperature of the products of combustion to about 350° C., and the amount of slack necessary to carbonize the coal is not over 8% of the coal coked. The gases from the oven are, therefore, all saved and can be used either as fuel gas or for illuminating purposes, as may be desired. If the oven is not built full depth, it is operated the same as the other types of by-product ovens, or still further, if desired, the oven can be built without the full depth part and operated with *Mond* producer gas. The capacity of the oven is from 6½ to 7 tons of coal in twenty-four hours or less, the speed depending entirely upon the quality of coal carbonized, the quality of coke desired, the width of the oven and the thickness of the side-walls. The construction of the oven is such that it is nearly gas-tight, and remains so under all changes of temperature which occur during operation. The illustration shows a section of a battery of ovens operated with the ordinary high-temperature producer. The producers are about five feet in diameter, receive their primary air and steam at a temperature of, approximately, 400° C. The temperature of the fuel is maintained in the neighborhood of 900° C. The gas passes into a general flue and is distributed through the flue into the different ovens with a producer operating from two to five ovens, the number depending entirely upon the conditions and requirements of the plant. The general flue, for distributing the gas, has fire clay plates for limiting the producer's supply to any number of ovens desired, and the producers can each, or all, be entirely cut off from the general flue, as well as each, or all, the ovens.

The secondary air is forced into the recuperators by means of an exhauster, and this exhauster compensates by means of a governor with the exhausters, which remove the gas from the ovens. In this way the pressure in the flues, and in the ovens, is always the same. Otherwise, the ovens are operated in general like the ordinary by-product oven.

THE BERNARD COKE OVEN.

BERNARD'S SYSTEM OF RETORT OVENS.

The accompanying plan and sections, Figs. 67 and 68, will show the Bernard's system of retort coke ovens.

This oven was designed for producing coke only; when it is further desired to save the by-products of tar and ammonia, the arrangement of the flues is changed from the vertical to a horizontal position.

Mr. Walter M. Stein, of Philadelphia, a metallurgical engineer and expert in the construction of coke ovens, has just completed the second battery of the Bernard coke ovens, for the New Glasgow Iron, Coal and Railway Company of Nova Scotia.

The first trial battery of these ovens has been in operation over a year. It consisted of 36 ovens; the second and recently completed addition has 18 ovens, making in all 54 coke ovens at this plant.

The coke is discharged from the ovens by a steam ram every 40 to 48 hours, according to the regularity or irregularity of the supply of coal for charging.

Each oven is charged with 6 gross tons of crushed and washed coal, containing 12 per cent. of moisture. The total daily charge for the 54 ovens is 162 gross tons of coal.

The one-half of the ovens, 27, discharged daily, gives from each oven 2¼ tons of marketable coke, with less than 3 per cent. of moisture. The aggregate daily product is therefore 60¾ gross tons of coke.

This exhibits a yield of good coke of fully 75 per cent., which has been carefully ascertained by coal charged into the ovens and the merchantable coke produced.

As Mr. Stein writes, " The cost of coke making at Nova Scotia is, on an average, 15 cents per ton; this includes taking the coal from the storage bin, charging it into the ovens, pushing the coke out of ovens, closing the oven doors, sealing them with loam and watering the coke.

" This work is performed by a party of nine men; they could with ease take care of six ovens more if necessary.

" These nine men are all ordinary laborers, with the exception of one, who has charge of the pushing engine.

" The coke is loaded on charging buggies by additional men, and conveyed to the blast furnace by an endless rope.

" It will be noted that a force of nine men is required for a plant of retort coke ovens, whether it consists of *ten or sixty ovens*.

" For more than sixty ovens, an additional force of nine men is necessary.

" The nine men operating this plant of 54 ovens are distributed as follows:

" Three fillers on top of ovens.

" Two on coke side and two on pusher side to clear the doors, level the charges of coal in the ovens and seal the doors with loam.

" One man is required to cool the coke with water as it is pushed out of the ovens.

" The ninth man is in charge of the engine for pushing the coke out of the ovens.

" A bank of sixty coke ovens is considered as affording a fair daily amount of work for the nine attending workmen.

" It will thus be seen that the maximum economy in the manufacture of coke in these ovens is only secured by a battery of sixty ovens."

The cost of washing the coal is somewhat below five cents per ton in summer and ten cents per ton in winter, indicating a yearly average for this work of 7½ cents per ton.

The whole cost of labor in making one ton of coke is as follows:

Work at washing plant	$0.07½
Work at coking plant	.15
Total	$0.22½

This is exclusive of repairs to ovens or machinery, supplies, etc., etc.

Mr. Stein further adds, in regard to the cost of repairs to the ovens per ton of coke: "I beg to say that these ovens have not cost in repairs $100 since they were started; the only repairs which will be required are the door blocks on the discharge side, where some scaling of brick corners occurs by the use of water in cooling the coke. Occasionally a hole is burned in bottom of oven by an irregular supply of air. At long intervals a door will crack, but this is infrequent.

"As a general rule, retort coke ovens, *well constructed and skillfully operated*, will require very little repairs during the first ten years. Three years ago, during a long strike of miners in Germany, I had the privilege of examining the inside of numerous ovens of various types, and they generally looked well inside, though all or nearly all of them *had been in continuous use for about ten years.* They appeared to be good for at least five years of additional work."

I have examined a sample of this Nova Scotia coke; it is quite firm and hard bodied and is a fairly good furnace coke.

This result has been mainly secured by the admirable preparatory work in washing the coal, a description of which by Mr. Stein is given on page 61.

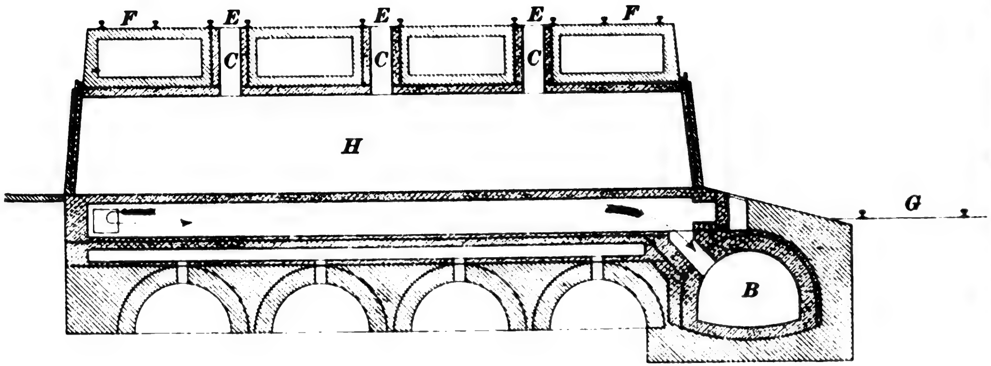
In reference to the cost of this bank of retort coke ovens, with coke discharge engine, it is somewhat difficult to say, as the materials for the experimental plant of 36 ovens were imported, which would add to the cost.

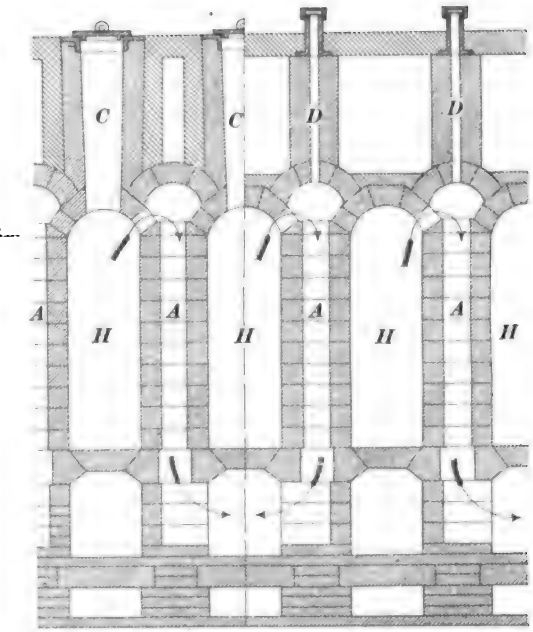
The principal elements of cost were as follows:

One coke discharging engine	$3,000
Iron parts of coke ovens, complete	9,000
Foundation of ovens and red brick	8,000
Fire brick, all imported	30,000
Superintendence, plans, etc., etc	5,000
Total	$55,000

The cost per oven is therefore about $1,000.

In the States of Pennsylvania, Ohio, West Virginia, Missouri, Illinois, Alabama and Kentucky, where excellent fire brick are readily and cheaply obtained, the cost of these ovens should be somewhat under the cost above stated.





DESCRIPTION.

A, Gas Flues.
B, Main Gas Flue.
C, Charging Holes.
D, Air Holes.
E, Tracks for Larries Charging Coal.
F, " " Windlass Raising Doors of Ovens.
G, " " Coke Pushing Machine.
H, Retort.

FIG. 67.—TWENTY-FOUR-HOUR RETORT COKE OVEN, BERNARD'S SYSTEM, WITHOUT SAVING OF BY-PRODUCTS.

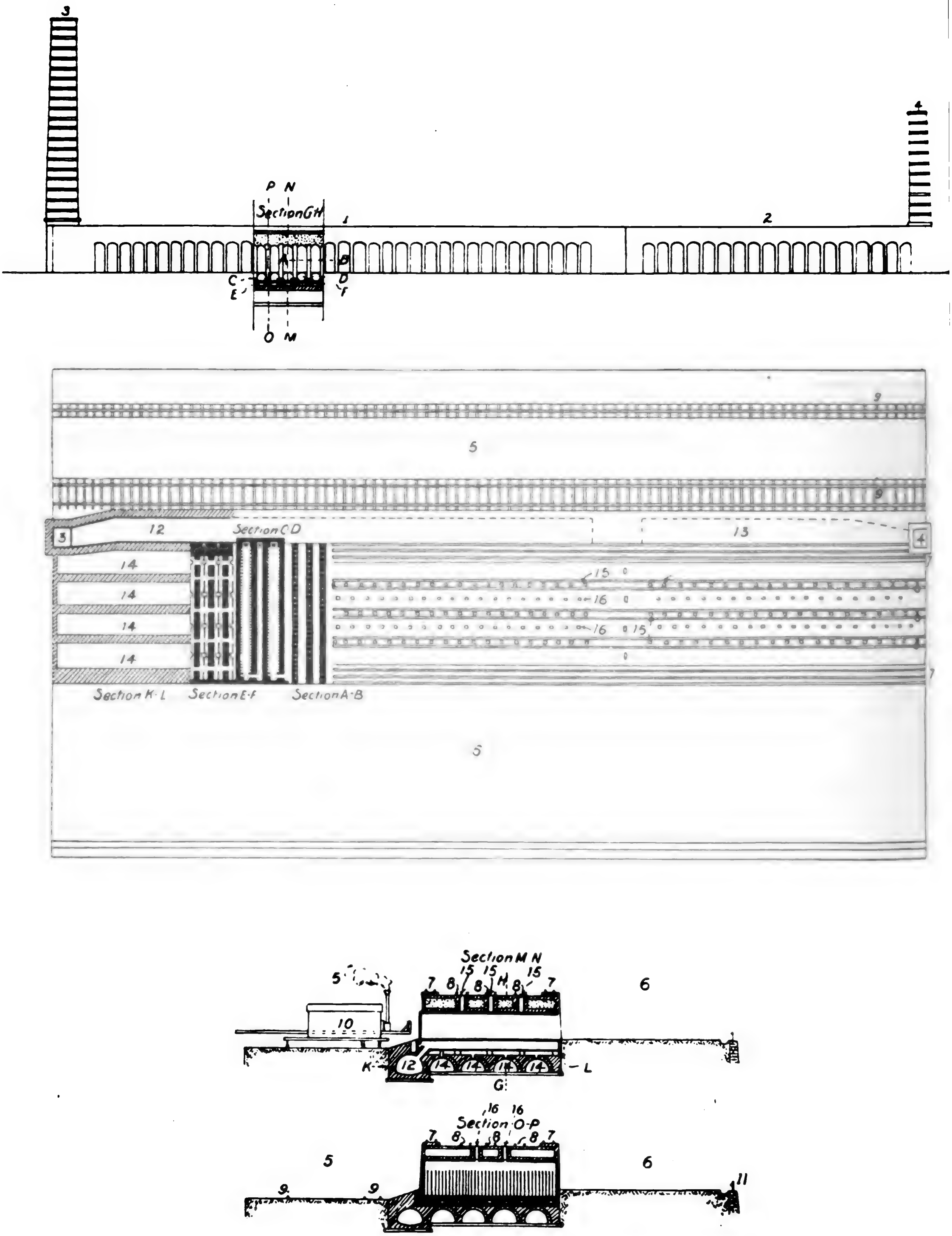


Fig. 68.—GENERAL PLAN OF 54 RETORT COKE OVENS, BERNARD'S SYSTEM, PATENTED. BUILT BY WALTER M. STEIN.

1. Battery of 36 Retort Coke Ovens, Bernard's System.
2. Battery of 18 Retort Coke Ovens, Bernard's System.
3. Chimneys for 1.
4. Chimneys for 2.
5. Side of Coke Pushing Machine.
6. Coke Discharge Side.
7. Tracks for Windlass for Raising Doors of Ovens.
8. Tracks for Larries for Charging Ovens.
9. Tracks for Coke Pushing Machine.
10. Coke Pushing Machine.
11. Water Supply.
12. Main Gas Flue of 1.
13. Main Gas Flue of 2.
14. Air Flues.
15. Charging Holes.
16. Air Holes.

THE SHREWSBURY OVEN.

Figs. 69, 70 and 71 show the construction of an oven designed to save the by-products, patented July 24, 1894, by A. D. Shrewsbury, of Charleston, West Va. In his specifications Mr. Shrewsbury makes the following claims:

The main object of my invention is to provide for an even and uniform distribution of the air over the surface of the coal, in a coke oven, and, at the same time, to heat the air before introducing it to the surface of the coal.

The other objects and details of construction of all the parts are fully described hereinafter.

For carrying out the first part of my invention I provide a second dome, forming thereby an intermediate chamber, communication with the oven itself, or coking chamber being brought about by holes at certain and equal distances apart, and uniformly distributed in the second, or inner dome. This chamber is divided in such a manner as to allow the air to be admitted, necessary for combustion, into one-half of the chamber, and from the second half of this intermediate chamber, leads a branch pipe which is connected with the main conduit into which the gases formed during combustion, are drawn off by an exhauster and condensed, forming thereby the several by-products which exist in the manufacture of coke.

My invention also includes means for cooling and condensing the gases in the conduit, thereby forming the by-products.

In the drawings, Figs. 69 and 70 are vertical sectional views of my improved coke oven and modifications. Fig. 71 is a plan view and a view of a detail.

The oven *A* may be of any desired form, either round, rectangular or square, and has an upper or outside dome and a lower or inner dome, marked *B*, forming suction chambers *C* and *C'* between them.

In order to charge the oven, the opening *D* is carried down the space going through the suction chamber and into the oven, similarly lined with fire bricks as is the oven itself. The usual means for charging the oven and stopping up the door may be employed.

The inner dome is perforated throughout its extent, and the holes *E* must be at regular distances apart, and so arranged that through all of them a uniform draft can be obtained, at one and the same time. This intermediate chamber, in Figs. 69 and 70, is divided equally into two parts, *C*, *C'* by a central wall in line with the opening *D*. The air is admitted in one side and is thence drawn down through the holes, as indicated by arrows, into the combustion chamber and there mixes with the gases and is drawn off through holes in the other half of the dome into the other half of the chamber *C'* by an exhauster and passes out by a branch pipe *F*, and thence into the main gas flue *G*, connected with the exhauster *H*, from which the flue leads to a condensation plant of any desired form. The air passing through the intermediate chamber and into the oven, as described, becomes

heated before entering the combustion chamber, and by this means the oven does not become cooled down by cold air entering.

It is of great importance that the outlet branch pipe *F* should be of a larger diameter than the inlet *I*, to allow for the expansion of gases. In this branch pipe or outlet *F*, is placed a damper in order to regulate the

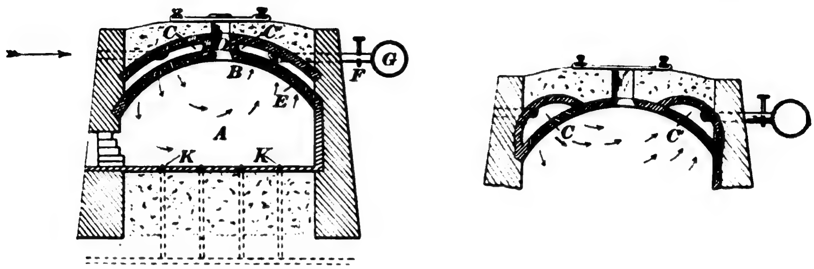


Fig. 69.

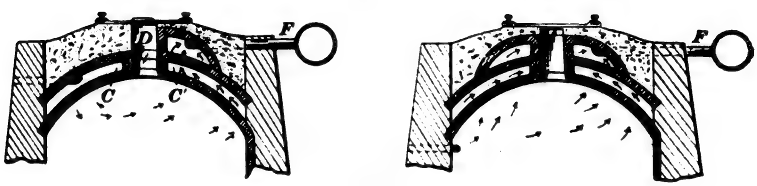


Fig. 70.

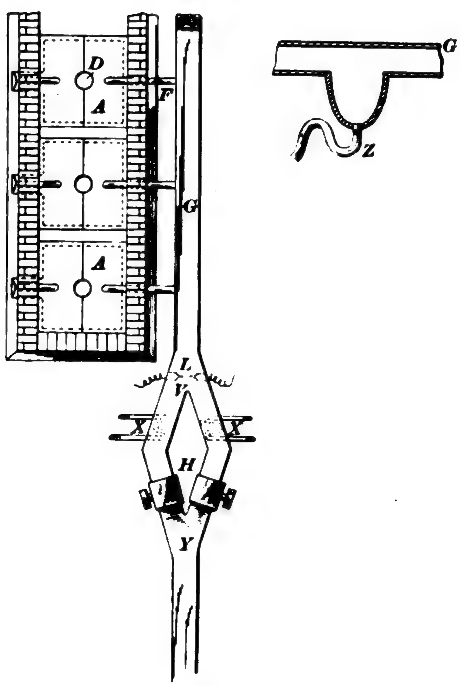


Fig. 71.

draft or to shut off the draft entirely, thereby not interfering with the exhauster that would be required for other ovens in blast at the same time. By this arrangement the suction draft is uniform throughout the entire area of the coal bed, and the coal being coked gives the gas from one part of the oven an equal opportunity to escape as from any other part. This results in a uniform action throughout the oven during the entire process of the conversion of the coal into coke, and brings about a uniform grade of coke, in color, weight and density, and prevents the oven from becoming hotter in one part than it is in another. It is a well accepted fact that through the inability to obtain a uniform heat in ovens now in use, coal is imperfectly coked and when an oven is drawn, a portion of the coke may come out black, showing a want of regular heat throughout the oven. This black coke, or badly coked coal, must be thrown on one side, and becomes so much loss, for it can be all used only when the coking process is perfect, and the coke is drawn from the oven all alike. The process of coking cannot be continued beyond a certain length of time in order to make up for this imperfectly coked coal, but must be drawn out to produce a certain grade of coke, for if this continuation be allowed, that which is already coked would begin to burn away, the carbon being consumed; hence the necessity of a uniform heat for the process of coking and which, in my invention, I am able to bring about.

In Fig. 69 I have shown modifications, the intermediate chamber being formed by separate arches. Also in Fig. 70 I have shown supplemental chambers, formed by arches or domes above the intermediate chambers and communicating therewith through a series of holes. These still further modify and regulate the draft.

In Fig. 70 the supplemental chamber is shown on the exhaust side only, and it also shows how it may be applied on both sides when the exhaust is through an undivided intermediate chamber.

In Fig. 71, a part of the exhaust pipe *G* is shown in section, showing the trap *Z* and the cooling coil.

Steam pipes *K* lead to the bottom of the oven and these have nozzles for introducing steam jets into and through the coal bed. All bituminous coals contain more or less sulphur in the form of sulphide of iron, or iron pyrites, and this moistening of the coal by steam, eliminates more readily the sulphur, and forming thereby sulphureted hydrogen gas, and practically produces a coke free of sulphur; it is not used for the purpose of combustion. Within the oven at proper points I arrange electro positive and electro negative elements connected with suitable circuit wires. The purpose of these elements is to secure a galvanic action within the oven to so act on the gases that they may be purified in such a manner that the chemical combination, arising from the decomposition of the various elements during the process of coking, may be brought about more readily,. and increase the amount of ammonia.

Other electro positive and electro negative elements are arranged in the main flue as at *L*, near the cooling device, where all the gases pass after leaving the oven, and a further extraction of the by-products takes place, uniting, in a chemical action, gases that might have passed out of the oven in a free state and so on into the main conduit.

The exhauster is indicated at *H* and the pipe *Y* leading therefrom to the condensation plant, not shown. I have provided means for cooling the gas in the main flue just before it reaches the exhauster in order to condense the ammonia and tar contained therein. This cooling means consists of a coil or series of ammonia or brine pipes *X*, intersecting the main gas flue in front of the exhauster and any suitable form of trap (Fig. 71) may be used, or catch pan arranged for collecting any of the by-products drawn from the gas.

I do not wish to limit myself to any particular coil of pipes nor to any particular series or form of trap, the essential principle being that the cooling device be arranged at a point in front of the exhauster. Two sets of cooling and condensing apparatus and traps may be employed, so that one may be cleaned while the other is in operation. For this purpose, the conduit *G* is divided at *V*, and each branch has a separate cooling coil and separate exhauster; both branches reunite at *Y* to the pipe leading to the condensation plant. It will be understood also, that the trap is in each branch, and that a suitable valve is located at the junction of the branches, to admit the current to one or the other of the branches.

By this apparatus the maximum effect is secured both in the production of coke and in the recovery of the by-products, for it will be clear that the uniform draft secured by the arrangement of the two domes and the suction chamber will secure an even distribution of the draft and a complete coking operation, while the action of the electro positive and electro negative elements, together with the cooling apparatus, effects the complete recovery of the by products.

I do not need to use two exhausters, as by providing a suitable valve at *V* and an exhauster in the pipe *Y*, the gas may be drawn through either branch while the other is being cleaned.

The exhauster mentioned herein is also a draft controller, as by it the draft through the oven is made more or less.

I claim:

1. In a coke oven, an intermediate chamber in the upper part of said oven, a division therein forming two parts, an air passage from the outside opening into one part of said chamber, an exhaust opening into the other part of said chamber and a series of passages between said oven and both parts of the intermediate chamber, substantially as described.

2. In a coke oven, an intermediate chamber in the upper part of said oven having communication with the interior of said oven, through a series of evenly distributed holes, a supplemental chamber communicating with

the intermediate chamber, through a series of holes, an exhaust passage communicating with the supplemental chamber, and an air supply pipe, all substantially as described.

3. In combination, with a coking oven, a main gas flue having branches both connected with the exhaust, and a cooling device and a trap in each branch, substantially as described.

WESTERMANN REGENERATIVE COKE OVEN.

The oven designed by Franz Westermann of Herne, Germany, and patented in the United States on July 9th, 1893, is shown in Fig. 72.

It shows a cross section through the center of the chambers *B B*, and a horizontal section, the upper half of which is taken just above the floor of the chambers, and the lower half is taken just below the same. The gases driven off by the coking operation pass out by the pipes *a*, *b*, *A* to a scrubber or condenser, and when cooled, return by the pipes *G*, *G*¹ to burners which project into the fire chambers *M* beneath the coking chambers *B*. The air to support combustion enters the fire chambers through ducts *l*, *l*¹ which lead from the regenerators *K*, *K*¹.

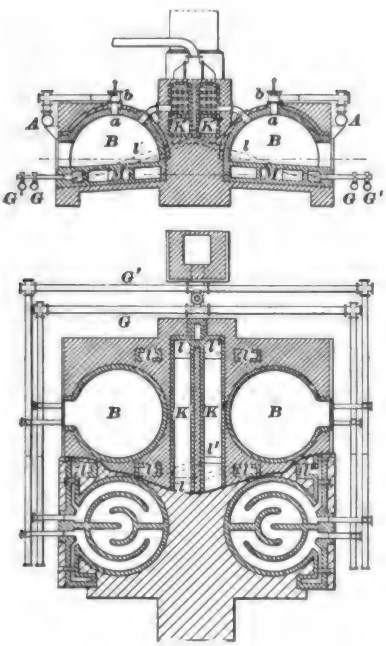


Fig. 72.

The hot products of combustion pass off by similar ducts to the other regenerator. Thus one regenerator is cooling while the other is heating up. They are changed off or reversed at intervals of thirty minutes to one hour, according to the nature of the coal to be coked. The coking chambers are of the common bee-hive shape, and are set in two parallel rows, as long as desired, with the two regenerators between them, and the two sides are worked alternately.

The necessary draft is obtained by a chimney, or by a blower if preferred.

THE A. HÜESSNER COKE OVEN.*

This is one of the forms of coke ovens built mainly for the saving of by-products in coking.

Mr. Hüessner, the inventor, is one of the early experts in the successful work of securing these products.

The flues in this oven are horizontal; similar in this respect to Simon-Carvès and the Semet-Solvay ovens. It differs from the Coppée and Hoff-

* Lunge—1887.

man types of ovens in the posture of its flues, as they have the vertical posture. The horizontal flued ovens afford a very uniform diffusion of heat in a simple and direct manner.

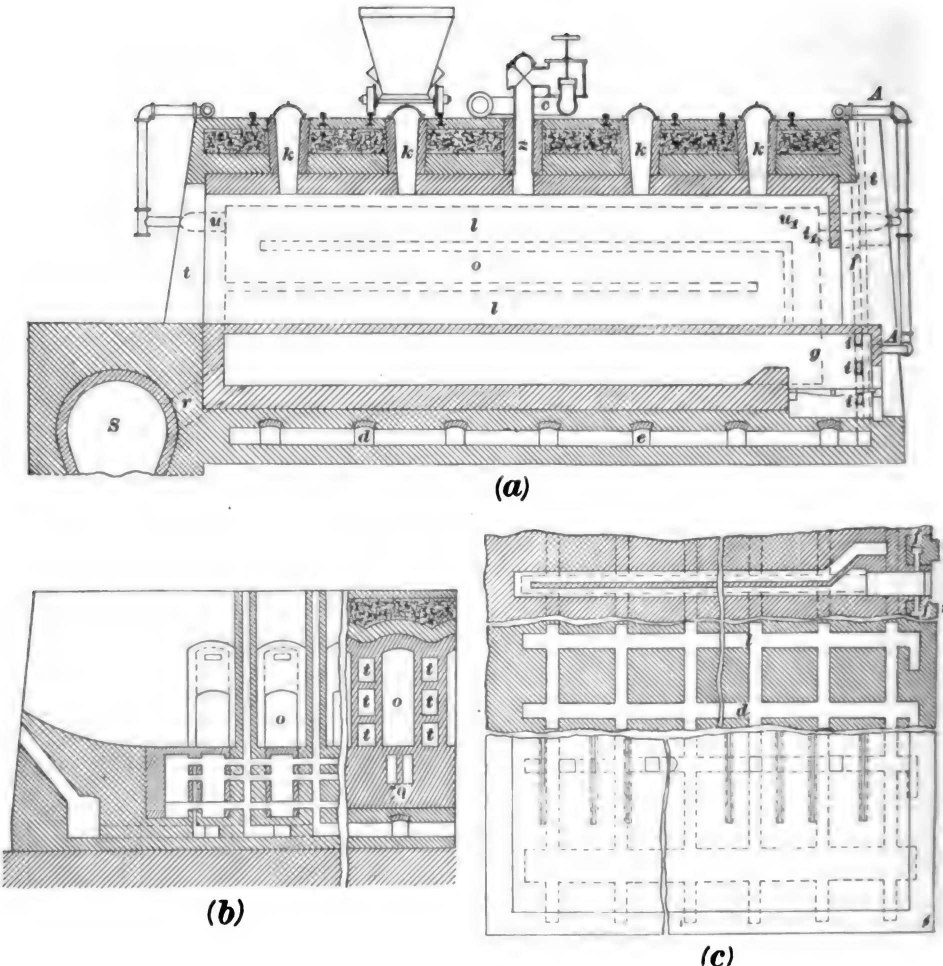


FIG. 78.

"The dimensions are: length, 29 feet 6$\frac{5}{8}$ inches, width in the middle, 1 foot 10$\frac{5}{8}$ inches, with a certain taper to facilitate the mechanical discharge of the coke, height, 5 feet 10$\frac{7}{8}$ inches. (The original Carvès oven is 19 feet 8$\frac{1}{4}$ inches, by 2 feet 5$\frac{5}{8}$ inches, by 4 feet 9 inches high.)

"The available space in the Hüessner ovens is 88 per cent. of the total space, and they take a charge of 5$\frac{1}{2}$ tons of finely sifted, dry coking coal.

"The charging takes place by 4 holes *k*, *k*; the ends are closed by doors turning on hinges; the discharging takes place by the usual steam pushing machine.

"The end walls between each two ovens are strengthened by buttresses *t*, (Fig. 73*c*), which at the same time prevent air from entering into the flues.

"The gases are aspirated by means of an exhauster through the outlet *m*, and are forced through the condensers and scrubbers; then return to the ovens, and issue by the tube *A* over the fire-grate *g*, where they take fire. The fire-gases travel round the partition *Z*, rise at one end and up to the top flue *l*, and descend through the three horizontal flues *ll* and the snore hole *r* into the main-flue *s*. The mouth of the gas-inlet pipe *A* is an annular double tube, like a Bunsen burner; whilst the inner tube conveys the air for combustion, the combustible gas issues through the annular space, and both enter at the same time into *g*. Owing to the distance which the products of combustion have to travel before they reach the main flue *s* (about 100 feet in Carvès' oven), they were formerly cooled down too much, whilst the oven bottoms were fluxed. To avoid this Hüessner (about the same time that Carvès took out his new patent in 1883), introduced a previous heating of the air to about 300° C. in the flues *d*, *e*; it is then conveyed through the small flue *f*, contained in the buttress *t*, partly through *i* into the grate space *g*, partly through *i* into the top flue *l*, and in both places gets mixed with gas. This does not seem to have met with complete success; but after adding further gas-inlets at *u* and u_1, the fire on the grate *g* could be left out, the gases sufficing for heating the retorts.

"The cost of erecting a set of 100 Hüessner ovens in Gelsenkirchen, Westphalia, according to a published balance sheet was:

"For ovens, buildings, machinery and iron wall, railroads and water supply, £300 per oven ($1,500).

"The ovens are charged, at intervals of 60 hours, with 5½ tons of coking coal."

They are stated by Hüessner to yield from good coking coal as follows:

Large Coke	75 per cent.
Small Coke	0.80 "
Coke breeze	1.20 "
Tar	2.77 "
Sulphate of Ammonia	1.10 "

A recent statement claims that from a charge of 7 tons of coking coal, 5 tons of coke are obtained in 48 hours. This shows a product of 71.43 per cent. of coke.

It is also submitted, that all the surplus heat from the ovens, can be returned to the steam boilers, or other uses, affording a much greater heat supply than is usually obtained by the use of a portion of the gas, deprived of the by-products, to the steam boilers. In the Otto-Hoffman ovens 40 per cent. is estimated for use in generating steam.

It is evident that this oven, from the substantial method in its construction, its horizontal flues and its simple requirements in its operation, is destined to meet the wants in the coking of a wide range of the several qualities of coking coal—with slight revision in its dimensions.

CHAPTER VI.

THE PHYSICAL PROPERTIES OF THE THREE PRINCIPAL FUELS USED IN METALLURGICAL OPERATIONS.

Law of Progress.—The Study of Fuels by Iron Manufacturers.—Charcoal, Anthracite Coal and Coke.—Prime Requisites.—Hardness of Body and Large Cells.—Early Times.—Charcoal, the Principal Fuel.—It Served its Turn in Forges and Low Furnaces.—It was *the Educating Fuel.*—Anthracite Coal a Natural Coke.—Hard, Dense and Slow in Combustion.—Coke with its Large Cells Affords the Best Conditions for Economy and Energy in Blast Furnace Work.—Beginning with 1850, Three Fuels at Service of Iron Workers.—Charcoal, Anthracite Coal and Coke.—Elementary Composition of these Fuels.—Study of their Physical Properties.—Development of Blast Furnace Conditions.—Table showing the Progress of these Fuels in Blast Furnace Use.—Table showing Comparative Work in Blast Furnace.—Furnace Test Decisive.—Physical Structure of these Three Fuels.—Requirements of Physical Structure.—Table showing Product of Coke in Round and Retort Ovens.—Otto-Hoffman Coke from Connellsville Coal.—Repressed Cell Structure in Retort Ovens.—General Table showing Physical and Chemical Properties of American and Foreign Cokes.—Results of Recent Experimental Tests of Coking Connellsville and Tuscarawas Coals in Retort Ovens.—Tabular Statement showing Details of Physical Tests.—Analyses of Coals and Cokes.—Percentages made over Theoretic Product.—Volume of Sulphur volatilized in Each Type of Oven.—Physical Character of Cokes made.—General Conclusions on Results of Tests.—Table comparing Work of Fuels in Furnaces.—Weight of Each Kind of Fuel to Smelt one Ton of Pig-iron.—Structure of Dense Coke approaching Anthracite Coal.—Sir I. Lowthian Bell on Physical Properties of Cokes made in Bee-Hive and Simon-Carvès Ovens.—Percentage of Coke produced in Each Type of Oven.—General Remarks on Relative Values of Cokes.—Economy of Making Coke in Retort Ovens.

The law of progress is universal. Beginning with the blade, then the ear, and ultimately the full corn in the ear.

The iron manufacturers have studied, under many years of practical experience, the properties and values of the principal fuels in general use for iron smelting—*charcoal, anthracite coal and coke.*

In these fuels, especially for blast furnace and kindred uses, the prime requisites are hardness of body to sustain the weight of furnace charges; to resist dissolution in the upper portion of the furnace and to enter into combustion with the utmost energy at the proper zone in the furnace.

These elements in the fuels are essential in the economical and vigorous working of the furnace.

In the early times, in iron making, charcoal was the principal, if not the only fuel used in forges and blast furnaces.

From its softness of body it could only be used in the old time forges and low furnaces with feeble blast in the initial operations of iron smelting.

It was the *educating fuel* in the early operations of iron smelting and iron working.

Anthracite coal is a natural coke. From its hardness of body it is abundantly able to sustain the pressure of the highest furnace charges, as well as to resist the dissolving action of carbon dioxide, but its extreme *density* of physical structure renders its combustion slow and its calorific energy moderate.

Between these two extremes of blast furnace fuels *coke*, comes to the iron manufacturer inheriting in harmonious combination the good properties of charcoal and anthracite coal.

It has hardness of body to sustain the burden of the highest furnace. This hardness enables it to resist dissolution in its passage down the furnace to the zone of combustion.

Its large surface space, from its *cellular structure*, affords full preparation before reaching the zone of fusion, which assures great calorific energy in its combustion.

Beginning with 1850 the three fuels at the service of the iron manufacturer consisted of *wood charcoal, anthracite coal and coke.*

These are composed as follows:

	Charcoal.	Anthracite.	Coke.
Moisture	3.50	2.50	0.49
Volatile Matters	6.49	4.00	0.011
Fixed Carbon	87.00	87.00	87.46
Ash	3.00	6.00	11.32
Sulphur	.....	0.50	0.69
Phosphorus	0.02	0.02	0.029

It required time to assure furnace managers of the special fuel best adapted for their use, considering cost, energy of fuel, and quality of pig-iron made.

During the past decade the examination of furnace fuels embraced not only their chemical constituents, but also their physical properties. This has led to the conclusion, that the physical structure is a very important factor in conferring energy in the combustion of the fuel. Rapid combustion, in the blast furnace, results in increased output with corresponding reduction of cost of pig-iron.

This intelligent study of the physical as well as the chemical properties

of these fuels in furnace use did not end here; but the correlated study of the form and size of the furnace, the heat and pressure of blast, have been put into successful practice in the smelting of iron.

This has led to the development of the fuel best adapted to these metallurgical operations, especially in the large blast furnaces for the production of Bessemer pig-iron.

The following table will show the use and growth of these three chief fuels in the manufacture of pig-iron from 1854 to 1890:

Years.	Charcoal.	Anthracite.	Coke.	Remarks.
1854.	342,298	339,435	54,485	All net tons.
1855.	339,922	381,866	62,390	Anth. leads Charcoal.
1869.	392,150	971,150	553,341	Coke leads Charcoal.
1875.	410,990	908,046	947,545	Coke leads Anthracite.
1890.	703,522	2,448,781	7,154,725	Era of Coke.

This table from Mr. J. M. Swank's "*Iron in All Ages*," exhibits in a very interesting way the struggle and progress of these fuels for supremacy in metallurgical operations.

The supreme value of coke, as exhibited in the large increase of its use in blast furnace operations, is further sustained by the following tabulated statement of actual furnace work:

COMPARATIVE WORK OF FUELS IN BLAST FURNACES.

Kind of Fuel.	Size of Furnace.	Output per month. Gross tons.	Location.	Iron Ore. Average Per cent. Iron.	Pounds of fuel to one ton pig iron.	Year.	General Remarks.
Charcoal	10½′ x 45′	1,488	Michigan.	59%	1844	1890.	Spring Lake Furnace—Lake Ore.
	10′ x 48′	2,615	Michigan.	60%	2060	1891.	Bay Furnace, Mich.—Lake Superior Ore.
	12′ x 60′	3,379	Wisconsin.	55%	1815	1890.	Hinkle Furnace, Ashland—Lake Ore.
Anthracite	17′ x 65′	2,698	New Jersey.	55%	2244	1890.	Secaucus, Hudson Co., N. J.—Hazleton, Anth.
Anthracite and coke.	15′ x 80′	3,844	Penna.	60%	2520	1892.	Schuylkill Anthracite—1309 lbs. to 1 ton pig. Connellsville Coke—1211 lbs. to 1 ton pig.
	15½′ x 55½′	2,565	Penna.	58%	2200	1885.	Schuylkill Anthracite—1650 lbs. to 1 ton pig. Connellsville Coke—550 lbs. to 1 ton pig.
Coke	12½′ x 60′	2,108	Virginia.	47%	2020	1890.	Ivanhoe Furnace—Pocahontas Coke.
	22′ x 90′	10,536	Penna.	59%	1737	1890.	Edgar Thomson—Connellsville Coke.
	22′ x 90′	12,000	Penna.	59%	1800	1892.	Connellsville Coke.

The furnace test, under justly equated conditions of work, is the *Supreme Court* of *fuel decisions*.

From it there can be no appeal.

It becomes, therefore, most important to the coke manufacturer to consider the essential elements in coke which have conferred on it the most distinguished place in the iron industry, so as to maintain in its manufacture these desirable properties.

If the physical structure of these fuels is examined, it will be found that charcoal consists of a series of longitudinal tubes, uniting with each other and affording ready passage to the furnace gases. The walls of these tubes are readily oxidized. Charcoal is, therefore, a pure and moderately energetic furnace fuel.

Anthracite coal is a natural coke, made under immense pressure, and very *dense* in its physical structure. It inherits no cellular structure, as it has been fused into a dense vitreous mass by the pressure and heat under which it was made, this great pressure repressing the cell development.

It is, from its physical structure, the least energetic of the fuels under consideration. Its action in a blast furnace is somewhat relieved, as under heat it decrepitates, and thus increases the extent of surfaces exposed to the oxidizing gases of the furnace, compensating in a measure for its density.

Coke, on the other side, has a structure made of a series of irregular, promiscuously disposed cells, with vitreous walls; these cells are connected by diminutive passages which afford free courses for the oxidizing gases of the blast furnace. It is these *hard* vitreous cell walls in coke that give it the superior value as an energetic fuel in blast furnaces.

From the foregoing it will be evident that the physical structure of coke, other things being equal, is the main element that confers on it the superior place it holds amongst blast furnace fuels.

The same is true, in a modified way, of charcoal fuel.

The anthracite coal holds the lowest rank.

The factor of the cost of these fuels is also an important element in determining their use in each locality. This, however, does not enter into the present investigation, except as a qualifying clause.

The main inquiry at this place is to determine the nature of the physical and chemical properties that are most desirable in coke for blast furnace use, and to meet, as far as possible, these requirements in the manufacture of coke.

It is evident that in the manufacture of coke the main efforts should be directed to produce a full cell structure, except in such conditions when the quality of the coal requires compression to avoid a too inflated cell structure.

These requirements in coke fuel are clearly defined under four distinct elements in its manufacture.

I. Hardness of body.

II. Full developed cell structure.

III. Purity.

IV. Uniform quality of coke.

In the further consideration of these valuable properties in metallurgical coke, it may be helpful to the manufacturer to consider these four essentials in detail.

I. HARDNESS OF BODY.

The best cokes possess a hardness of body of 2.0 to 3.0. By this is meant *hardness of body or cell walls—not density*—for dense cokes are usually soft or punkey; whilst hard bodied cokes are generally well developed in cellular structure.

These two physical properties, hardness of body of coke and full cell spaces, are correlated, just as softness of body and density are associated.

The coal from which soft coke is made, lacks the element that fuses and hardens, and is, therefore, deficient in these prime essential qualities.

The nature of this fusing element or elements in coking coals has not been clearly defined, at least such information has not come under the notice of the writer.

The solution of this question, of the elements in coal which contribute to its fusion in a coke oven and assure hardness of body with large cell spaces, is most important; for if they were known, equivalent elements could be supplied to coals deficient in them, thus improving the quality of coke in its most essential requirements.

This prime necessity of hardness of the body of coke will be evident, when the conditions of its combustion in a blast furnace are considered.

In its movement down the furnace, to a short distance above the tuyeres, it is enveloped in the ascending currents of hot gases, mainly carbon dioxide; this gas possesses the power of dissolving carbon or coke, and is especially destructive to the soft variety.

Sir I. Lowthian Bell, in his treatise on the Manufacture of Iron and Steel, page 287, gives the following:

"Hard coke, soft coke and charcoal pounded as near as possible to the same size were placed in a hard glass tube which they filled, and were then raised to a good, red heat in a Hoffman's double furnace.

"During the space of 30 minutes, 800 c. c. of carefully dried carbonic acid was passed over each specimen.

"The issuing gases had the following volumetric composition:

	Hard Coke.	Soft Coke.	Charcoal.
Carbonic acid	94.56	69.81	35.2
Carbonic oxide	5.44	30.19	64.8
	100	100	100"

It will thus be evident that every pound of coke dissolved by this gas, before reaching the efficient zone of combustion, is a double loss, reducing the heat of the furnace and disarranging its regular operations.

The following table of careful tests of hardness of body and development of cells will prove interesting:

Locality.	Grammes in One Cubic Inch.		Pounds in One Cubic Foot.		Percentage by Volume.		Compressive Strength per Cubic Inch, 1/4 Ultimate Strength.	Height of Furnace Charge, supported without crushing.	Order in Cellular Space.	Hardness.	Specific Gravity.
	Dry.	Wet.	Dry.	Wet.	Coke.	Cells.					
Standard Coke.											
Connellsville	12.14	21.34	46.30	81.25	43.73	56.27	236	94	1	3.0	1.69
Syracuse, N. Y..........	15.02	23.41	57.20	89.20	47.68	52.32	340	136	1	2.6	1.91
Morris Run, Pa..........	13.02	22.41	49.03	85.37	41.82	58.18	246	97	1	2.3	1.90

NOTE.—The Connellsville Coal was coked in Bee-Hive ovens. Morris Run Coal, Tioga Co., Pa., coked in Semet-Solvay ovens, at Syracuse, N. Y., and same quality of Morris Run Coal coked in Bee-Hive Coke ovens near the mines.

In the treatment of "dry" coals, the hardness of the body of the coke can be increased by coking such coal in the narrow or retort coke ovens.

The cell structure in this kind of ovens is always more or less depressed as compared with the full cellular development in coke made in the Bee-Hive class of ovens.

In any type of oven, maximum heat is required to produce the hardest bodied coke, but it is not conducive to the largest output of by-products.

II.—WELL DEVELOPED CELL STRUCTURE.

The coals best adapted for coke making will usually afford, in conjunction, ample cellular development and hardness of body.

The value of full cell structure in coke will be readily appreciated when it is considered that such fuel presents the largest surface for oxidation in a blast furnace.

The desirable ratio of cellular space to the cell walls or body of the coke, has been carefully determined, and found to be as 44 to 56 nearly. That is, the cubic contents of coke body to cell space, is as 43.73 per cent. of coke to 56.27 per cent. of cells.

The evidence, by filling these cell spaces with water under the receiver of an air pump, clearly shows the thorough connections by passages of all the cells in the coke.

The calorific energy of the coke fuel in the crucible of a blast furnace, also shows how easily and thoroughly the blast penetrates these cell spaces and maintains rapid combustion.

It is impossible, however, to make good coke from coal that is wanting in the elements that assure thorough fusion in the coke oven.

Inferior coking coals can be coked by special oven treatment, but the coke from such coal is always of a lower quality.

No condition of oven treatment can make good coke from bad coking coal.

The table below exhibits, in a marked manner, the repression of cell development when Connellsville coal has been coked in Otto-Hoffman retort coke ovens, as compared with the structure of coke made from same quality of Connellsville coal and coked in the modern Bee-Hive coke oven.

Locality.	Grammes in One Cubic Inch.		Pounds in One Cubic Foot.		Percentage by Volume.		Compressive Strength per Cubic Inch, ½ Ultimate Strength.	Height of Furnace Charge, supported without crushing.	Order in Cellular Space.	Hardness.	Specific Gravity.
	Dry.	Wet.	Dry.	Wet.	Coke.	Cells.					
Standard Coke.											
a. Connellsville........	12.51	21.62	47.69	82.20	43.93	56.07	301	110.	1	3.0	1.74
b. Otto-Hoffman Oven...	14.64	21.02	55.79	80.07	61.13	38.87	465	186	1	3.1	1.80
c. " " " ..	20.49	24.23	78.07	92.30	77.22	22.78	940	376	1	3.5	1.82

NOTE.—*a*. Coke made from Connellsville coal in Bee-Hive ovens.
b. **Coke from sides of Otto-Hoffman oven, from Connellsville coal.**
c. **Coke from bottom of Otto-Hoffman oven, from Connellsville coal.**

In the presence of these facts, in regard to the repression of cell development in retort coke ovens, it becomes a matter of great interest to determine, whether the increased hardness of body of the retort oven coke, will compensate in blast furnace work for the greatly diminished cell space in this coke.

It will require furnace determinations to adjust the relative loss and gain from these related physical conditions.

III.—PURITY.

Carbon is the source of heat in coke. Other properties being equal, the larger the percentage of carbon the greater the volume of heat.

As coal has had its genesis in vegetable matter, it usually inherits 3% to 7% of ash. A coke, therefore, not greatly exceeding 10% of ash, can be regarded as an average clean fuel.

Cokes inheriting only 5% to 7% of ash, are regarded as exceptionally pure.

The sulphur in coke should be under one per cent., if the fuel is to be used in metallurgical operations. The best cokes contain only ½ to ¾ of one per cent. of this impurity.

Ordinarily, the volume of sulphur in coal is in a certain proportion to its slate or ash; but there are exceptions to this relationship where coal high in ash is quite low in sulphur.

The reduction of the slate in coal by washing or picking generally reduces the percentage of sulphur. About 40% of it is volatilized in the coke oven.

Phosphorus is found present in coke. In the purest varieties it runs from 0.012% to 0.029%.

At present no treatment is known that will reduce the phosphorus in coal or coke.

IV.—UNIFORM QUALITY OF COKE.

The uniform quality of the coke is one of the important requirements, in view of what has been noted of the destructive action of carbon dioxide gas on soft coke. The "black ends" which are sometimes made in coking, have to be included in weighing charges for the furnace, and its ready dissolution reduces the heat power in the proper zone of the furnace.

As this defect can be controlled by the manufacturer of coke, no reasonable defense can be urged for the presence of "black ends" in coke made for furnace use.

It has been shown that the use of coke is quite large and increasing, in the manufacture of iron and steel.

The large number of coke-making establishments in the United States, assure the truth of the foregoing statement.

The following table will show the physical as well as the chemical properties of American and Mexican cokes. In examining this table it will readily appear that in the best coke, the aggregate of cells space to body of coke is in the relation of 44:56 nearly.

It is not submitted that all coking coals can be made to assure this ratio of cells to body of coke, but in the coals best adapted for making coke a close approximation to these physical relations will be found.

TABLE EXHIBITING THE PHYSICAL AND CHEMICAL PROPERTIES OF COKE.

LOCALITY.	Grammes in One Cubic Inch.		Pounds in One Cubic Foot.		Percentage by Volume.		Compressive Strength per Cubic Inch, ¼ Ultimate Strength.	Height of Furnace Charge, Supported Without Crushing.	Order in Cellular Space.	Hardness.	Specific Gravity.	CHEMICAL ANALYSIS.						REMARKS.
	Dry.	Wet.	Dry.	Wet.	Coke.	Cells.						Fixed Carbon.	Moisture.	Ash.	Sulphur.	Phosphorus.	Volatile Matter.	
Standard Coke.																		
Connellsville	12.51	21.65	47.69	82.20	43.93	56.07	272	108	1	3.0	1.74	87.05	0.88	10.61	0.74	0.006	0.67	Bee Hive Oven.
Caledonia, Pa	12.10	21.80	46.12	83.07	40.83	59.17	149	59	1	3.0	1.81	87.89	0.13	9.42	1.57	0.024	0.39	48 Hour Coke.
Caledonia, Pa	13.57	22.41	51.69	85.38	46.07	53.93	209	84	1	3.0	1.80	......	......	......	......	......	......	72 Hour Coke, Bee-Hive Oven.
Walston, Pa	13.77	22.58	52.61	86.01	46.25	53.75	316	126	1	3.0	1.82	85.08	0.31	12.00	2.05	0.006	2.61	Bee-Hive Oven.
Reynoldsville, Pa	12.44	22.17	47.39	84.48	40.63	59.37	181	73	1	3.0	1.87	87.11	......	11.77	1.80	0.011	1.12	Bee-Hive Oven.
Richland, Pa	12.38	22.05	46.59	84.02	41.05	58.95	245	98	1	3.0	1.84	80.48	0.50	16.47	1.42	0.014	1.13	Bee-Hive Oven. 48 Hour.
Bennington, Pa	10.89	20.98	41.49	79.94	38.43	61.57	212	85	1	2.4	1.74	87.40	......	11.55	1.89	0.013	1.05	Miller Seam, Bee-Hive Oven.
Gallitzin, Pa	11.91	21.99	45.37	83.79	38.49	61.51	213	85	1	2.9	1.89	89.25	......	9.55	1.46	0.016	1.20	Miller Seam, Bee-Hive Oven.
Lilly, Pa	13.39	20.61	51.02	78.54	55.95	44.05	170	68	1¼	2.4	1.47	89.80	......	8.21	0.46	0.08	1.50	Miller Seam, Bee-Hive Oven.
Indian Creek, Pa	23.35	27.48	88.94	104.68	78.80	25.20	933	373	1	2.6	1.92	86.10	0.22	11.97	1.70	......	1.01	
Latrobe, Pa	15.74	23.62	59.97	89.99	51.93	48.07	299	120	1	3.0	1.85	87.539	0.081	10.90	0.744	.....	0.736	This Latrobe Coal was Coked in Germany.
Coosa, Ala	12.34	22.19	50.94	86.37	39.93	60.07	192	77	1	3.0	1.88	85.753	0.094	11.544	2.435	0.064	0.174	
Blocton, Ala	14.32	22.52	54.56	85.80	49.97	50.03	409	164	1.2	2.6	1.75	92.76	0.153	6.94	0.74	0.0066	0.81	Bee-Hive Oven.
Pineville, Ky	13.31	19.90	50.71	75.82	59.80	40.20	274	109	1½	2.5	1.37	91.56	0.43	6.36	0.61	0.013	1.04	Hull, Wyman & Cairn, Bee-Hive Oven.
Pineville, Ky	14.10	22.24	53.73	84.73	50.37	49.63	227	91	1½	2.6	1.71	94.66	1.14	3.78	0.59	0.007	0.41	Cumberland Colliery, Bee-Hive Oven.
Powellton, W. Va	14.16	22.93	53.88	87.33	46.48	53.52	163	66	1¼	2.6	1.86	91.048	0.117	7.548	0.626	0.007	0.661	
Montana, W. Va	14.28	22.82	54.39	86.95	47.87	52.13	327	131	1	3.0	1.82	84.33	4.00	8.77	1.67	0.010	2.90	48 Hour Unwashed Coal, Bee-Hive Oven.
Monongah., W. Va	12.63	22.05	48.11	84.02	42.33	57.67	306	122	1	3.1	1.82	89.77	0.23	9.80	0.976	0.039	0.80	72 Hour Washed Coal, Bee-Hive Oven.
Big Stone Gap, Va	11.89	21.18	45.31	80.70	43.34	56.66	245	98	1¼	2.5	1.67	92.05	0.29	5.60	0.74	0.009	1.32	48 Hour Coke, Bee-Hive Oven.
Big Stone Gap, Va	12.20	21.02	46.49	80.09	46.22	53.78	326	131	1¼	2.7	1.61	93.81	0.63	3.63	1.01	0.005	1.98	72 Hour Coke, Bee-Hive Oven.
Pocahontas, Va	15.67	23.58	59.68	89.64	52.07	47.93	236	94	1	2.5	1.83	92.694	0.345	5.882	0.738	0.0063	0.341	
Salville, Va	11.64	21.87	44.35	83.32	37.61	62.39	200	80	1	2.8	1.89	87.93	0.13	10.27	0.79	......	0.876	
Lonaconing, Md	10.22	21.29	38.92	81.12	32.43	67.57	90	36	1	2.1	1.92	84.667	0.614	12.234	1.465	0.0241	1.02	
Hondo, Mex	9.78	20.69	37.89	78.85	34.41	65.59	158	63	1¼	2.1	1.77	83.07	0.43	14.24	0.82	0.019	1.39	Washed Coal, Bee-Hive Oven.
Alamo, Mex	12.04	22.09	45.88	84.18	38.67	61.33	146	58	1¼	2.5	1.89	83.[illegible]	......	14.85	1.08	0.005	1.35	Washed Coal, Bee-Hive Oven.
Cardiff, Wales	12.90	22.27	49.16	84.86	42.76	57.24	231	92	1	2.5	1.84	[illegible]	0.06	4.26	0.685	0.018	......	
Syracuse, N. Y	15.02	23.41	57.20	89.20	47.68	52.32	340	136	1	2.6	1.91	86.04	0.23	12.81	0.56	0.005	0.92	Semet-Solvay Oven, Syracuse.
Morris Run, Pa	13.02	22.41	49.08	85.37	41.82	58.18	246	97	1	2.3	1.90	89.36	0.36	8.99	0.76	0.011	1.29	Bee-Hive Oven.
Anthracite Coal	......	......	.....	......	100.00	......	......	......	......	2.5	......	87.00	3.50	8.00	tr.	0.011	6.49	Wyoming Coal.

In a recent series of experimental tests in coking Connellsville coal in the Otto-Hoffman oven, and in testing Connellsville and Tuscarawas coals in the Hüessner oven in Germany, the following physical and chemical determinations will exhibit the properties of the cokes made in these ovens. The Connellsville standard Bee-Hive coke is given for comparison.

LOCALITY.	Grammes in One Cubic Inch.		Pounds in One Cubic Foot.		Percentage by Volume.		Compressive Strength per Cubic Inch, ¼ Ultimate Strength.	Height of Furnace Charge, Supported Without Crushing.	Order in Cellular Space.	Hardness.	Specific Gravity.	CHEMICAL ANALYSIS.						REMARKS.
	Dry.	Wet.	Dry.	Wet.	Coke.	Cells.						Fixed Carbon.	Moisture.	Ash.	Sulphur.	Phosphorus.	Volatile Matter.	
Connellsville-Standard..........	12.51	21.62	47.69	82.20	43.93	56.07	272	108	1.	3.0	1.74	86.88	0.79	11.54	0.695	0.005	1.81	Bee-Hive Oven (a)
" Hüessner	14.09	23.09	53.68	87.97	45.08	54.92	400	160	......	......	......	......	......	......	......	......	......	
" "	16.00	24.02	60.96	91.52	51.09	48.91	410	164	......	......	......	......	......	......	......	......	......	
" "	15.34	23.61	58.45	89.95	49.57	50.43	325	130	......	......	......	......	......	......	......	......	......	
" "	14.55	23.19	55.44	88.35	47.22	52.78	418	165	......	......	......	......	......	......	......	......	......	
" " Average	14.99	23.73	57.18	89.45	48.24	51.76	387	155	1.	3.1	1.89	86.38	0.03	13.08	0.63	0.015	0.51	Hüessner Oven (b)
Tuscarawas-Hüessner.........	10.96	21.13	41.76	80.51	37.94	62.06	164	66	......	......	......	......	......	......	......	......	......	
" "	11.78	17.25	44.88	82.45	39.88	60.12	163	65	......	......	......	......	......	......	......	......	......	
" "	11.09	21.86	42.25	83.29	40.41	59.59	172	69	......	......	......	......	......	......	......	......	......	
" "	10.72	21.05	40.84	80.20	37.00	63.00	124	50	......	......	......	......	......	......	......	......	......	
" " Average	11.14	20.82	42.43	61.61	38.81	61.19	156	62	1.	2.5	1.75	84.21	0.13	12.91	3.71	0.015	2.75	Hüessner Oven (c)
Connellsville-Otto-Hoffman " " Side of Oven..	14.64	21.02	55.79	80.07	61.13	38.87	465	186	......	......	......	......	......	......	......	......	......	
Bottom " ..	20.49	24.23	78.07	92.30	77.22	22.78	940	376	......	......	......	......	......	......	......	......	......	
" " Average	17.57	22.62	66.93	86.18	69.17	30.83	702	281	1¼	3.3	1.90	85.60	0.12	12.26	0.52	0.006	2.02	Otto-Hofman Oven (d)

Chemist—a, T. T. MORRELL.
" b–c, HUGO CARLSSON.
" d, DR. J. J. FRONHEISER.

The analyses of the coals used in these coking tests are are follows:
Hugo Carlson, chemist.

	Connellsville, Pa.		Tuscarawas, Ohio.	
Moisture, 212° F	0.84		2.53	
Volatile combustible matter	31.60		44.11	
Fixed carbon	59.86		46.28	
Ash	7.70	100	7.08	100
Sulphur	0.82		3.49	
Phosphorus	0.008		0.004	
Theoretic coke	68.06%		55.45%	

The analyses of the cokes made from the above coals as below:

	Connellsville, Pa.		Tuscarawas, Ohio.	
Moisture, 212° F	0.03		0.13	
Volatile combustible matter	0.51		2.75	
Fixed carbon	86.38		84.21	
Ash	13.08	100	12.91	100
Sulphur	0.63		3.71	
Phosphorus	0.015		0.015	

The product of marketable coke from the Connellsville coal is given at 70.10%; the coke from the Tuscarawas coal is stated at 61.47%. The percentage of breeze and ashes is not given separately, but these have no value in blast furnace work.

As the Connellsville coal affords 70.10% of useful coke, it will require 1.426 tons of coal to make 1 ton of coke.

The theoretic product of coke from this coal, 68.06%, would require 1.469 tons of coal to make one ton of coke, showing a gain from deposited carbon in coking of 2.9%.

The Tuscarawas coal gives 55.45% of theoretic coke, requiring 1.80 tons of coal to make one ton of coke.

As the oven yield is 61.47%, the deposited carbon is 9.79%, exhibiting this large accretion of carbon from the tar of this rich bituminous coal.

It will be readily seen, that in the process of coking the Connellsville coal in the Hüessner oven, 45% of the sulphur has been volatilized.

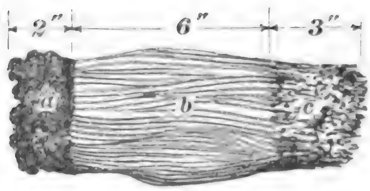
In coking the Tuscarawas coal, 46% of the sulphur has been eliminated.

In furnace operations about 4% of the sulphur goes over to the pig iron. As the Connellsville coke contains 0.63% of sulphur, it would contribute to the pig iron 0.0252% of this element, which would be slightly increased from the sulphur in the ore and flux, but these are usually small. The sulphur limit in the best Bessemer pig is .04 to .05%.

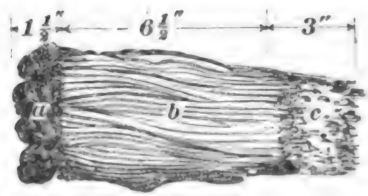
The Tuscarawas coke is too high in sulphur for use in the manufacture of pig iron.

In examining the physical structure of these cokes, the effects of the Hüessner oven in exerting a certain pressure to the charge in coking is quite evident in both these cokes.

There are three sections of different densities in the structure of these cokes, as shown in Fig. 74.



Connellsville.



Tuscarawas.
Fig. 74.

Beginning on the sides of the oven, section *a* contains one to two inches of the most dense portion.

The section *b*, 6 to 6½ inches long, contains fairly well developed cellular structure.

Section *c*, next to the middle division of the coal in coking, is greatly inflated in its cells, extending about 3 inches from its central end.

In making these determinations, Connellsville coke made in Bee-Hive ovens was tested by three samples each of 48 and 72 hours coke. The table, therefore, affords a general average of the physical properties of this standard coke.

In the Connellsville and Tuscarawas cokes, made in Germany, in the Hüessner retort oven, four samples of each quality of coke were used. The table gives these determinations in full, with the general averages of each kind for comparison.

The tests of the coke from Mr. Frick's Connellsville coal, made in Germany, in the Otto-Hoffman oven, consisted of two average samples from the top and bottom of the oven.

The determinations of the physical properties of the Hüessner-Connellsville coke show considerable variation in density, the general averages exhibiting an increased density of structure from the Bee-Hive-Connellsville of 7.7%.

. The coke is lumpy. It shatters easily into finger pieces, on planes nearly at right angles to the side walls of the oven. It does not inherit the silvery coating that gives the Bee-Hive-Connellsville coke such a desirable appearance.

The Hüessner-Connellsville coke is somewhat harder bodied than the Bee-Hive-Connellsville coke. It is probable that the increased hardness of body of the former will compensate for the carbon glaze of the latter. Both hardness of body and carbon coating protect coke in its passage down a blast furnace from the dissolving agency of hot carbon dioxide.

The Hüessner-Tuscarawas coke is lumpy and dark colored, shattering quite easily under slight shocks, into slender pieces on similar planes as the Hüessner-Connellsville coke.

The largest volume of the sulphur in the Tuscarawas coal is found as bisulphide of iron (FeS_2). In the process of coking, one equivalent of sulphur is volatilized, leaving the mono-sulphide (FeS) in the coke.

Disintegrating and washing this quality of Ohio coals would reduce the sulphur.

The Otto-Hoffman-Connellsville coke is the hardest bodied fuel, exhibiting good work in the oven. But its largely increased density reduces its value as a vigorous blast furnace fuel.

It is, on general average, 45 per cent. denser than the standard Bee Hive-Connellsville coke, and 40.4 per cent. denser than the Hüessner-Connellsville product.

It approximates in its most dense sections to anthracite coal. It may be submitted, however, that the samples furnished over a year ago, by Dr. F. Schniewind, of Cleveland, were very select as to completeness in coking and density of structure.

It has been determined, by actual furnace work, that for the attainment of the maximum efficiency of coke fuel in metallurgical operations, two prime elements are absolutely necessary—hardness of body and full developed cell structure.

The following table will show the work of fuels, accurately determined, for calorific energy and economy in American blast furnaces :

Kind of Fuel.	Size of Furnace.	Output Per Month, Gross Tons.	Location.	Average Per Cent. Iron Ore.	Pounds Fuel to 1 Ton Pig Iron.	Year.	Remarks.
Charcoal	12′ x 60′	3,379	Wisconsin.	55[illegible]	1815	1891	Bay Furnace
Anthracite	17′ x 65′	2,698	New Jersey.	55[illegible]	2244	1890	Secaucus Furnace
Anthracite and Coke	15¼′ x 55¼′	2.565	Pennsylvania.	58[illegible]	2200	1885	....
Coke	22 x 90	12,000	Pennsylvania.	59[illegible]	1800	1892	Edgar Thompson ConnellsvilleCoke

From the foregoing results in blast furnace practice, it will appear that in the physical condition of the fuels two conditions have been established, with their relative consumption of fuel and pig iron produced. The first is the work of the Connellsville standard coke in the Edgar Thompson blast furnaces, where the smelting of one ton of Bessemer pig iron has been accomplished with 1800 pounds of coke. In the other, 2200 pounds of anthracite coal was required to perform similar work.

The monthly outputs of the coke and anthracite fuels indicate their relative calorific energies.

As this great difference, in fuel energy, has not its source in their chemical composition, it follows that it must be found in their physical structure.

In this structure there are two terms of relative density, in the anthracite coal 100, and in the standard Connellsville coke 44. It is self evident that any increase in the density of the coke towards that of anthracite coal is just so much of an approach to this slow acting fuel, and hence its value in furnace work is depreciated in direct proportion; perhaps more so in the coke than in the anthracite coal, as the latter decrepitates in the presence of furnace heat and thus presents enlarged surfaces to the combining gases in combustion, whilst the coke does not break up under heat, and is therefore directly less energetic.

It was evidently for such reasons that Sir I. Lowthian Bell, in comparing the work performed in his blast furnaces by coke made from Bears Creek coal in Bee-Hive and Simon Carvés retort coke ovens, remarks as follows:

I.	II.	III.
" Mixtures from Colleries usually supplying Clarence works and made in Bee-Hive Ovens.	Bears Creek Coke made in Bee-Hive Ovens.	Bears Creek Coke. made in Simon Carvés Ovens. (Retort Ovens.)
100.	101.11.	111.11.

" In comparing the two kinds of Bears creek coke, II and III, if No. II is taken as a 100, then No. III will stand as 109.89, exhibiting an inferiority of nearly 10% in efficiency in smelting one ton of No. 3 iron.

" The average consumption of the three fuels was 2520 pounds, 2548 pounds, and 2800 pounds respectively."

On the other side, with careful work in coking, the percentages of large coke made in Bee-Hive, Hüessner and Otto-Hoffman ovens are as below:

Bee-Hive oven	65%
Hüessner oven	70%
Otto-Hoffman	70%

The yield in the retort ovens is, therefore, nearly 8% above the yield afforded by the Bee-Hive oven.

This increased yield in the retort oven coke, will compensate in part for its increased density, requiring increased quantity to perform equal work with the Bee-Hive product.

In the investigation of the comparative merits of these two coke fuels, the vital inquiry is, will 65 units of Bee-Hive coke perform as much work in the blast furnace as 70 units of the denser retort fuel?

This inquiry can only be satisfied by careful and extended tests of both qualities of fuels in blast furance work.

In addition to this, there is some economy in labor in the retort ovens, by the mechanical discharge of the coke from the oven chamber, with the further revenue which can be derived from the saving of the by-products of tar and ammonia sulphate, which could not be so largely secured in the Bee-Hive type of oven.

CHAPTER VII.

THE LABORATORY METHODS OF DETERMINING THE RELATIVE CALORIFIC VALUES OF METALLURGICAL FUELS.

Furnace Work the Standard Test.—This Work to be Properly Adjusted to Each Fuel.—The Results Noted.—Economy, Speed, Purity of Metal.—Analyses and Work of Fuels in Blast Furnaces.—Charcoal a Special Fuel too Scarce to Compete.—Essential Fuel Requisites.—Hardness.—Cell Development.—Hardness of Body—Resists Dissolution by CO_2.—Sir I. Lowthian Bell's Tests—Hard and Soft Cokes.—Loss Indicated by Volume of CO.—The Double Value of Large Cells in Coke in the Furnace.—Weight of These Fuels to Smelt One Ton Pig Iron.—Density of Anthracite—Slow Combustion.—The Physical Structure of Cells Gives Calorific Energy.—Ratio of Cells to Body of Coke.—Relation of Anthracite to Coke in Calorific Energy as 1 to 3.—Method of Laboratory Determination of Fuel Values.—Coke Cubes—Cells Filled with Water by Air-pumps.—Dr. Sterry Hunt's Easy Methods.—Mills' and Rowan's Observations on Coke Determination.—Sources of Variation.—Coke Cubes Used to Ascertain Burden Bearing Property.—Hardness of Body Requires Careful Determination.—Laboratory Report on Pineville Coke.—Proved by Furnace Test.—Dr. Fronheiser's CO_2 Tests.—Table.—Compressive Strength of These Fuels.—From These Data Accurate Results Can Be Made of the Calorific Values of Metallurgical Fuels.

There can be little difference of opinion in deciding that the test in blast furnace use of the three principal fuels is the most reliable method of determining their relative calorific values, provided the conditions of the work are equalized justly.

This assumes that such tests shall have been made in blast furnaces whose dimensions have been proportioned to assure the best possible results in the fuel used; not only this, but that the pressure and heat of blast have been in harmony with the requirements of the fuels, in order to accomplish their complete combustion and economical application.

It is further assumed, that in these practical determinations of the calorific values of these fuels in blast furnace work, three chief considerations shall have been accurately noted: First, the weight of fuel to smelt one ton of pig iron; second, the time required in smelting; and third, the purity of the fuel.

The first shows the economy in fuel; the second, economy in the cost of superintendence; and the third, exemptness from dangerous impurities in the pig metal produced.

The following table exhibits approximately, the work of the three chief fuels in blast furnace operations:

Kind of Fuel.	Proximate Analyses.					Size of Furnace.	Per Cent. of Iron in Ore	Pounds of Fuel to 1 Ton Pig Iron.	Output Per month, Gross Tons.	Relative Values Charcoal at 100.			Locality.
	Moisture.	Volatile Matter.	Fixed Carbon	Ash.	Sulphur.					Economy.	Speed.	Purity.	
Charcoal..	3.50	6.49	87.00	3.00	tr.	12′ x 60′	55	1,815	3,379	100	100	100	Wisconsin
Anthracite	2.50	4.00	87.00	6.00	0.50	17′ x 65′	55	2,244	2,698	123	80	97	New Jersey
Coke	0.49	0.01	87.46	11.32	0.89	22′ x 90′	59	1,737	10,536	96	311	94	E. Thompson Penna.

It is assumed that the related conditions in these furnaces, were practically alike.

As charcoal is too expensive for general use in blast furnaces, except for special grades of pig metal, further consideration will embrace only two fuels—*Anthracite* coal and *Coke.*

It is further submitted that the above practical results, in actual furnace work, afford sure standards for laboratory determinations of the value of fuels for metallurgical purposes.

It has been shown that the two chief essential physical requirements in fuel for blast furnace use, are, *hardness of body* and *well developed cell structure.*

The first essential physical requirement of hardness of body is important, in protecting the fuel in its downward passage in a blast furnace from loss in dissolution by carbon dioxide. Sir I. Lowthian Bell has long ago pointed out the fact, "that the carbon, as it exists in different qualities of coke, is not influenced in the same degree by this solvent power of CO_2; that the soft description, known as black ends, being more easily attacked than the hard silvery-looking kind."

In two tests, with hard and soft bodied coke, Mr. Bell proves that the hard coke, pulverized to the size of mustard seed, exposed at a temperature of melting zinc, for three quarters of an hour, to a current of CO_2 gave a mere trace of CO.

The soft coke, similarly treated, in one and one quarter hours gave 92 c. cs. of CO.

This indicates the loss that the soft variety of coke suffers by dissolution in the blast furnace.

In the second requirement, the valuable results from full development of cells in coke are readily understood, as these cell spaces afford free entry to the ascending hot gases, permeating the coke thoroughly, and imparting to it a high temperature which aids materially in its rapid combustion.

In addition to this, the large area of the cell spaces affords ample surface for the hot oxygen of the blast to act on, securing rapid combustion with high temperature and calorific energy, resulting in the rapid working of the furnace.

Now anthracite coal is not lacking in hardness of body. In this physical property it is equal to the average cokes. We have seen, however, that it requires 2,244 pounds of anthracite coal to do the work of 1,737 pounds of coke in a blast furnace. It is evident, therefore, that the property of hardness of body alone will not afford the best results in smelting pig iron.

The great *density* in this fuel confers on it the slowest combustion in a blast furnace.

Only for the decrepitation, which takes place near the tuyers, its rate of combustion would be further retarded.

On the other side, coke possesses an average hardness equal to the anthracite coal; but any slight difference of hardness of body cannot be urged to account, in any important degree, for the great difference in the calorific energy of coke over anthracite coal in blast furnace operations.

As the difference in the calorific efficiency of these fuels has not its exclusive genesis in the physical property of hardness of body alone, it is evident that it must be looked for elsewhere.

This has been discovered to be in the *cellular structure of the coke*, other conditions being equal.

In the best varieties of coke the aggregate volume of the cell spaces to the body of the coke is as 44 to 56 nearly.

In some cokes this cell structure is too inflated, conferring on it brittleness in furnace work, with lack of energy at the tuyers.

From these conditions, in the anthracite and coke fuels, it is evident that in the best varieties of each, we have, from actual work in the furnace, two different results: in the anthracite a dense, languid fuel, and in the coke a cellular, vigorous fuel. The ratio of the former to the latter in calorific energy or speed is as about 1 to 3, assuming that they have about the same or equivalent chemical composition.

From these tests of the physical properties of these two important metallurgical fuels the following methods of determining the values of all qualities of coke for blast furnace or similar uses have been established.

An average sample of the coke is carefully and accurately cut into inch cubes. One or more of these cubes, depending on the accuracy required in the determinations, is thoroughly dried, and when cooled, carefully weighed.

This gives the weight of the body of the coke in its dry condition. The cubes are then immersed in a vessel of distilled water and put under the receiver of an air pump, the air pumped out of and the water forced into the cells.

The cube or cubes are again weighed, the difference in weight equated

to the specific gravity of the coke gives the aggregate cell space in the cube of coke.

An easier method is suggested by the late Dr. Sterry Hunt, in the Report of the Geological Survey of Canada, 1863–6, pages 281–3.

His method is to select suitable specimens of any size or shape, usually pieces from 20 to 40 grammes in weight; these are to be dried and weighed; then fill their cells with water and weigh in water; the pieces are then taken out of water, the excess of water on their surfaces carefully removed, and weighed again in air. These operations furnish all necessary data for calculating the following properties:

I. The apparent specific gravity, or the relationship between the whole mass of material and an equal volume of water.

II. The true specific gravity or the specific gravity of the body of the coke or other matter.

III. The aggregate of cell space in 100 volumes of material, or percentage of cells by volume.

IV.—The volume of cells in a given weight of material, as c. c. in 100 grammes.

The loss in weight of the material saturated with water, being equal to to the volume of water displaced by the mass, enables us to determine the specific gravity of the latter; while this loss in weight, less the weight of the water absorbed by the mass, gives the true volume of water displaced by its body, and hence the means of determining its specific gravity.

The division of the amount of water absorbed, by the amount of water displaced, gives the amount of volume of the cells in a unit of the material, and the division of the weight of the water absorbed by the weight of the dry mass, gives the aggregate volume of cells in a unit of the mineral; let

a=the weight of the dry material.

b=the weight of water which it can absorb.

c=the loss in weight, in water, of the saturated material.

Then $c : a :: 1000 : x$=the apparent specific gravity, or the specific gravity of the mass.

$c—b : a :: 1000 : x$=true specific gravity, or specific gravity of the body of the mineral, water being 1000.

$c : b :: 100 : x$=percentage by volume of the cells in the mineral.

$a : b :: 100 : x$=volume of cells in 100 parts by weight of the mineral say c. c. in 100 grammes.

In coke determinations, Messrs. Mills and Rowan, in *Chemical Technology*, Philadelphia, 1889, submit the necessity of some changes in the foregoing methods, as follows:

"Suitable specimens from 20 to 40 grammes in weight were selected to represent the average physical condition of the coke. They were thoroughly brushed to remove any loosely adhering particles which might fall off during the experiments, and thus vitiate the results, and were weighed

just as received; they were dried at a temperature of 100° C. for one hour, cooled under the desiccator and weighed, the loss in weight representing the amount of moisture found in the specimen as received.

"Great difficulty was experienced in thoroughly filling the cells with water, on account of the small adhesion between the surface of the coke and the water, but, after considerable experimenting the following general plan was adopted.

"In filling porous substances generally with water, two methods are in use —one to soak the specimens in water for a time and then to place them in water under the receiver of an air pump, and exhaust until no more air is given off; and the other to keep them suspended in boiling water until the pores (cells) are filled with water, as is shown by their ceasing to gain in weight on taking them out, cooling and weighing. In this case it was found more expedient to use a combination of these two methods.

"In the determination of the specific gravity, there are two sources of variation, one inherent in all specific gravity determinations, and unavoidable, the other accidental and in a measure disappearing in the averages. The first error is due to the possible pressure of water-tight pores, or cells, causing a minus error in the determinations. The other error is due to the possible presence in a piece of coke of a small piece of slate, causing a plus error."

The cubes of coke, in the former method, when dried, or others that have not been wet, are then used to determine the capacity of the coke for bearing furnace burdens without crushing, in a machine for testing the compressive strength of materials.

The hardness of the body of the coke is determined by the usual methods: but when great care is required, the resistance of a cube of coke to abrasion, under specific pressure and speed on an emery wheel, is used to ascertain this important property of hardness of body.

With the data obtained under these methods, it is demonstrated, that an accurate estimate can be made of the calorfic value of the coke for blast furnace purposes, as the following estimate, followed by a blast furnace test will show:

In October, 1891, Mr. J. H. Allen, Vice-President and General Manager of the Cumberland Valley Colliery Company, Pineville, Kentucky, sent a sample of his coke for examination and estimate of its value as as metallurgical fuel: The following table and report were returned to Mr. Allen:

FULTON'S TABLE EXHIBITING THE PHYSICAL AND CHEMICAL PROPERTIES OF COKE.

Revised Series.

LOCALITY.	Grammes in One Cubic Inch.		Pounds in One Cubic Foot.		Percentage by Volume.		Compressive Strength per Cubic Inch, ¼ Ultimate Strength.	Height of Furnace Charge, Supported Without Crushing.	Order in Cellular Space.	Hardness.	Specific Gravity.	CHEMICAL ANALYSIS.						REMARKS.
	Dry.	Wet.	Dry.	Wet.	Cok.	Cells.						Fixed Carbon.	Moisture.	Ash.	Sulphur.	Phosphorus.	Volatile Matter.	
Standard Coke.																		
Connellsville	15.47	23.67	58.98	87.34	49.96	50.01	301	120	1	2.5	1.89	87.46	0.49	11.32	0.69	0.029	.011	Bee Hive Oven Coke.
Pineville, Ky	14.10	22.24	53.73	84.73	50.37	49.63	227	91	1	2.1	1.71	94.66	1.14	3.78	0.59	0.007	0.41	" " "

Dear Sir : In compliance with your request of September 17, I have examined the sample of your coke which you forwarded for this purpose. Assuming that this sample of your coke, submitted for chemical and physical examination, is a fair average of its quality, I have had seven physical tests made, giving the average of the seven in the accompanying table. In this table, the Connellsville coke is included for purposes of comparison between this and other cokes. On general principles, coke for metallurgical uses should possess hardness of body with well developed cell structure so as to insure exemption from combustion in the upper regions of a blast furnace, and to afford the utmost calorific energy in the lower region of the furnace. Hardness of body in coke prevents its dissolution by the furnace gases, in a section of the furnace where it is not only a waste of fuel but where it disturbs the orderly working of the furnace. The large cell development in coke assures its calorific energy in combustion.

The coke you have submitted from your Pineville works, shows that it has been carefully and intelligently treated in the coke ovens. There are no indications to show where an improvement could be suggested in this respect. The coke has the usual slender columnar structure somewhat peculiar to Kentucky cokes. It will be seen in the table that the cellular structure of this coke is somewhat below the standard Connellsville.

This slight physical defect is compensated, in a great measure, for blast furnace use by the slender finger structure of the coke as it comes from the coke ovens. Its burden bearing qualities are equal to the highest blast furnaces now in use or likely to be attempted in time to come. The hardness of this coke is so near that of the Connellsville standard, that it is not necessary to draw any special distinction. The chemical analysis shows that it is a much purer fuel than that of the Connellsville standard. The ash is remarkably low, only one-third of the volume found in the Connellsville. As a clean fuel, it has few if any superiors. It will also be noted that the exceptionally low percentage of the element phosphorus in this coke gives it special adaptibility for smelting Bessemer pig iron. The sulphur is low, under that of the standard. *It will be found a very superior fuel for blast furnace purposes, for smelting iron in cupolas, and for all metallurgical purposes in which coke is used as a fuel.*

JOHN FULTON, E. M.

Immediately following this report, a shipment of this coke was forwarded to the Nashville Furnace Company for an actual test of its value in this furnace.

The following letter shows the result of this furnace test of Pineville coke.

NASHVILLE, TENNESSEE, October 31, 1889.

Messrs. J. D. ANDERSON & CO.,
Nashville, Tennessee,

Gentlemen : In reply to your favor of this date, we have to say that on the 23d, 24th and 26th inst., we made a test at our furnaces of the Cumberland Valley Colliery Company's Pineville coke. As the coke was new to us, we, as a matter of prudence, charged light in the beginning, using 4,000 lbs. of ore, 2,100 lbs. of lime and 2,800 lbs. of coke. The furnace being too hot on the 23d, we increased the ore to 4,800 lbs. The furnace still being too hot on the 24th inst., we increased to 5,300 lbs., *being the same burden we had carried with Pocahontas coke, with as good results.* When we came to understand the nature of the Pineville coke, we produced as much iron and a higher grade of iron than we had previously done with other cokes.

Yours, &c.,
(Signed) H. W. BUTTORFF,
President and Genl. Manager.
J. H. HANLY,
Supt. and Furnace Manager.

An additional test has recently been introduced, in determining the resistance of coke to the dissolving agency of hot carbonic acid gas, which proves the relative hardness of body in anthracite and coke fuels.

Average samples of each kind of fuel are powdered and thoroughly dried. About 800 c. c. is placed in a test tube. Hot carbonic acid gas is passed over the powdered coke during a fixed time. The coke is carefully weighed as it is placed in the tube, and after it is taken out the difference in weight shows the loss by dissolution and the relative hardness of body in resisting dissolution by this test.

The following table exhibits some tests made in this way, by the late Dr. James J. Fronheiser.

Kind of Fuel.	CO_2.	CO.	Hardness.	Remarks.
Anthracite Coal	96.0	4.0	2.5	
Connellsville Coke	94.5	5.5	3.7	Coked in Otto-Hoffman Ovens.
Connellsville Coke	91.9	9.0	3.0	Coked in Bee-Hive Ovens.
Morris Run	88.8	11.2	2.6	Coked in Semet-Solvay Ovens.
Bennington	86.1	13.9	2.4	Coked in Bee-Hive Ovens

The percentages in the CO column indicate, approximately, the probable loss in these fuels from softness of body.

The following statement shows the ultimate average compressive strength of the above fuels, per cubic inch, without crushing:

Anthracite Coal	3,000	lbs.		
Connellsville Coke	2,260	"	Coked in	Otto-Hoffman ovens.
Connellsville Coke	1,204	"	"	Bee-Hive ovens.
Morris Run Coke	1,360	"	"	Semet-Solvay ovens.
Bennington Coke	848	"	"	Bee-Hive ovens.

From the foregoing data, it will readily appear, that laboratory determinations of the properties of these fuels will afford very accurate results in estimating their several calorific values in metallurgical operations.

CHAPTER VIII.

THE LOCATING OF PLANTS FOR THE MANUFACTURE OF COKE.

Importance of Right Location.—Its Bearing on Profits of Coke Making.—Best Location Secured by Employing Expert Engineers.—Economy in Such a Course.—Location Governed by Topography.—Gradients of Railroad Sidings and Larry Tracks Should be Balanced to Economize Haulage.—One Foot per 100 Feet of Descending Gradients.—Disposal of Ashes and Breeze.—Plan Illustrating Location of 100 Ovens at Bennington.—Description and Criticism.—Morrell Works, 400 Ovens, in the Connellsville Region.—General Description with Suggestions.—Plan of Coal Storage Bins, with Hoppers for Loading Coal into the Charging Larries.—Mahoning Plant, Old Time Arrangement, but Economical.—Double Handling of Coke Objectionable.—Leisenring No. 3—500 Ovens—H. C. Frick Coke Co.—Head House and Bins for Loading Larries.—General View of these Works.—Description and Criticism.—The Twin Plants of the Oliver Coke and Furnace Co.—Plans Showing Methods of Location, with full Details.—The Two Coke Plants of the Hostetter Coke Co.—A Modern Plant.—General Description.—Details.—Consideration of Economy in Compacting Ovens.—Tenement Houses, Double and Single.—Location of Retort Coke Oven Plants.—Requirements Differ from the Bee-Hive Plans.—Bernard's Ovens, with Crusher and Elevator.—Wharves and Pusher Track.—Steam Ram for Pushing Coke Out of these Ovens.—Section of McLanahan's Pusher.—Plan of its Track and Method of Supplying it with Steam.—The Semet-Solvay Plant at Syracuse.—Gradients of Oven and Sidings Tracks.—New Departure in Locating Coke Ovens at Steel Plant, Lorain, Ohio.—The Economy in the Movement.

In former chapters the methods of preparing coal for making coke with the ovens adapted for producing the best metallurgical fuels have been considered.

It is evident that the first important effort that should elicit the full attention of the manufacturer of coke is, to produce it of a uniform first-class quality.

This will assure his product a ready market, and secure his men continuous work at the ovens in the usual times of uninterrupted business.

The second effort relates to a consideration of how, in the economies of location of a coking plant, full profit can be secured to the manufacturer.

It is assumed that wise coke makers do not enter this branch of industry alone in the interest of science, but reasonably expect moderate compensation for capital invested, time devoted to the industry and exhausting coal supply.

In order to secure this second condition, as far as it can be controlled by the location of the coking plant, it will readily appear that this element

in affording economy in the coking operations requires careful consideration.

Without in the least undervaluing the good, practical judgment of the coke manufacturer, it may be submitted that it will conduce to economy to secure the professional service of an expert engineer in the work of locating the coke oven plant.

Sometimes a few dollars are saved by not employing a competent engineer to waste in the end a great many.

In common with modern progress in the economical location of industrial plants, the arrangements of the coking plant and its source of coal supply should receive the benefits of recent improvements in these respects.

The principles that evidently should govern the location of a coking plant consist in affording full facilities in the performance of all the work in the manufacture of coke with its resultant in economizing this labor.

The location, however, is governed in part by the topography of the locality in which it is designed to establish the work. The general plan will require to conform to these conditions.

It may be noted that the site for the coke ovens is frequently determined by the location of the coal mine opened for the supply of the ovens.

A little preliminary careful attention in the location of the coal mine with a view of affording the best possible ground for the ovens would generally conduce to economies in both.

In the location of plants of coke ovens of one or more banks the gradients of the larry tracks on the ovens as well as the tracks of the railroad sidings, should afford descending grades of at least 1 per cent., so as to secure the movements of the larries and railroad cars by gravity, thus avoiding mainly the use of locomotives or horse power in these operations.

Attention should also be given to facilitating the disposal of the waste products of ashes and coke dust, as these elements accumulate largely, even in a plant of moderate size.

The water supply should be pure and the quantity ample at all seasons of the year, with a medium pressure, to afford a full supply of water and prevent wear to the hose or injury to the brick work of the ovens by an over pressure in the water discharge.

In retort coke ovens, where the coke is cooled on the outside of the oven, the regulation of pressure in the water supply would only refer to the wear on the connecting hose.

The following outline plans of located coke ovens will serve to illustrate some typical examples of Bee-Hive and retort oven plants. They are not designed to convey the idea of perfectness in this respect, but to indicate where progress in the future methods of location should be attained.

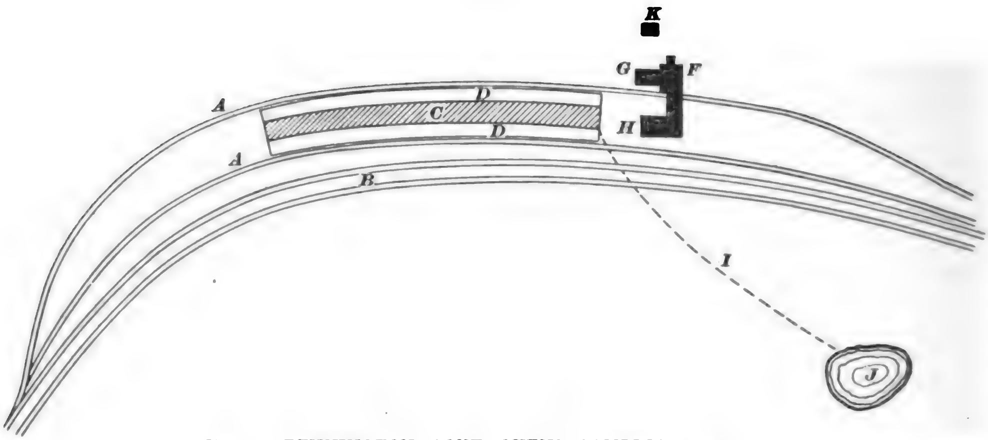


FIG. 75.—BENNINGTON COKE OVENS, CAMBRIA IRON CO.

Description.

AA, Railroad Sidings.	*C*, 100 Coke Ovens.	*G*, Engine.	*J*, Pond.
B, Pennsylvania R.R.	*DD*, Coke Wharves.	*H*, Coal Hopper.	*K*, Office.
	F, Shaft House.	*I*, Water Pipe.	

Fig. 75 shows the location of a plant of 100 Bee-Hive coke ovens at Bennington, near the large Allegheny tunnel of the Pennsylvania Railroad.

The ovens were located to be supplied with coal from a shaft 90 feet deep, which was in operation several years before the ovens were built in 1878.

The ovens are in a double line in a bank 700 feet long. The ground on which they were located was in such a posture as to compel conformity in alignment and grade to the line and grade of the Pennsylvania Railroad at this place. The gradient is about 90 feet per mile, which is considerably in excess of the requirement for gravitating larries and railroad cars on the sidings and coke oven tracks.

The coal is hoisted to a platform about 40 feet above the level of shaft and deposited in a large coal bin having a double series of hoppers underneath, through which the coal is loaded into the larries for charging the coke ovens.

The loaded larry is controlled, down grade, by one man, using a brake. It is returned to the coal bin by mule power.

The coal bin holds a supply of 300 to 400 tons of coal. This amount of supply stock is necessary to secure the prompt charging of the ovens, as the coke drawers begin work much earlier in the morning than the coal miners.

The immediate charging of the ovens, after the coke has been drawn out, retains heat and facilitates the coking operations.

The railroad sidings are extended above and below the ends of the coke oven bank, so as to afford room to receive a supply of empty coke cars on each side at the upper end and to drop down below the ovens the loaded coke cars to be taken out by the railroad trainmen.

To facilitate the loading of coke, the wharves have been made 25 and 30 feet wide; they are about 7 feet high above the top of the rails on sidings.

This plant affords fairly good facilities for economical work. The rather steep grades, on the ovens and railroad sidings, require careful handling of the larry and railroad cars to prevent wrecks, especially in the winter season.

The Morrell plant, in the Connellsville region, illustrates the method of location of a group of four banks of coke ovens, each bank containing 100 Bee-Hive ovens.

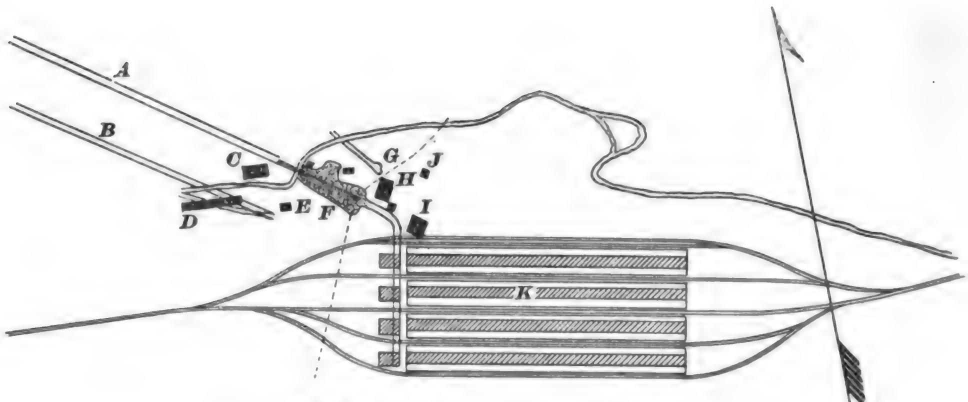


FIG. 76.—MORRELL COKE WORKS, CAMBRIA IRON CO.

A, Morrell Slope. *D*, Stable. *G*, Air Shaft. *J*, Blacksmith Shop.
B, Manway. *E*, Office. *H*, Boiler House. *K*, 400 Coke Ovens.
C, Car Shop. *F*, Coal Pile. *I*, Engine House.

Fig. 76 shows the general location of ovens, tipples, bins and railroad sidings.

In locating at this place it was found necessary to open the mine by a slope driven down the coal seam, which is 8 feet thick and has an inclination or dip of 5½ degrees to the northwest.

The coal is raised by extending the plane of the slope until it attains an elevation of about forty feet above the level of the tops of the coke ovens.

The Bee-Hive coke ovens are located in four parallel banks, each of which is 700 feet long.

Each bank of ovens has its flanking wharves. These wharves afford ample space for drawing the coke from the ovens and loading it on railroad cars. The wharves are twenty-five feet wide and seven feet high.

The ground on which these ovens have been located has a gentle inclination eastward, with sufficient descent to enable railroad cars and charging larries to be moved down grade by gravity.

The railroad tracks have been arranged so as to afford ample room for receiving empty coke cars at the upper or west end of ovens, and to permit the shifting of the loaded cars below the ovens.

No locomotive power is used at this plant. A man shifts the railroad cars from the upper sidings and places them at points along the wharves for loading with coke. When loaded they are then shifted down to the sidings below the lower end of coke ovens.

The only power used is horses or mules in hauling the empty larries back to be filled under the coal-bin hoppers.

These coal bins are constructed of heavy framed timbers, with white oak plank lining. Each bin holds 300 to 400 tons of coal.

There is one bin, with a double line of hoppers, to each bank of 100 ovens. See Fig. 78.

These coal storage bins afford ample supplies, so that the ovens can be charged promptly after the coke has been drawn out.

The coal is brought from the mine to the platform along the front of these bins, and is there dumped into any of the compartments in the usual manner.

Horses or mules are used in the movements of the mine cars from the head of the slope plane to these bins.

This arrangement has been found to work with economy. A device, consisting of an endless wire rope, with grip, might be used for this work of delivering loaded cars and returning the empty ones to head of plane with economy.

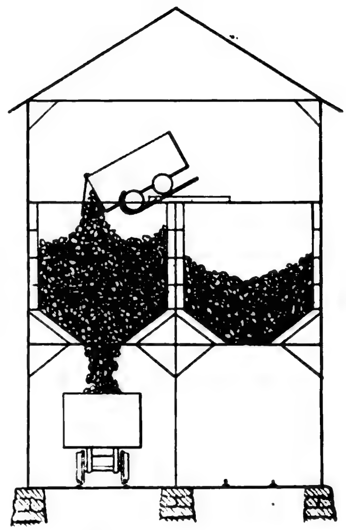


FIG. 78.—COAL STORAGE BIN.

This plant was constructed in 1880 by the Cambria Iron Company of Johnstown, Pa.

The water supply comes from Youghiogheny river. It is pumped to an elevation affording sufficient head to supply the ovens and the tenement houses at this and the Wheeler plants.

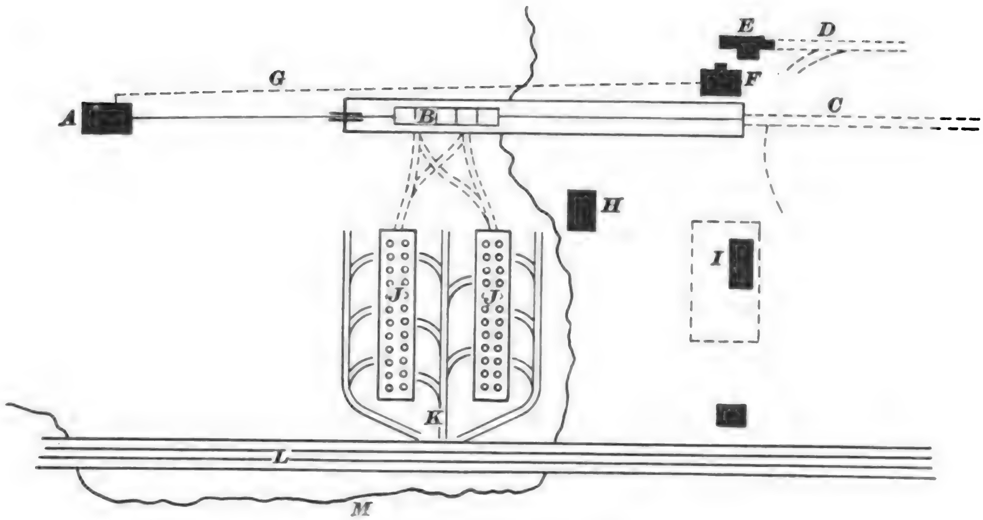


FIG. 79.—MAHONING PLANT.

Description.

A, Engine House.	*C*, Slope.	*F*, Boilers.	*I*, Stables.	*L*, Pennsylvania R. R.
B, Coal Hoppers.	*D*, Manway.	*G*, Steam Pipe.	*J*, 100 Coke Ovens.	*M*, Creek.
	E, Fan.	*H*, Repair Shop.	*K*, Loading Place.	

Fig. 79 shows the location of 100 Bee-Hive coke ovens in two sections, at the Mahoning Works, near Dunbar, in Fayette County, Penna.

It is an example of the early method of location, at a place of limited room. The ovens have, therefore, been placed in two short lines.

The slope here is down the coal bed, which dips at an angle of 5½°, and has a thickness of about 8 feet.

The mine coal cars are hauled up to the hoppers in trips of six or more cars, on a single track. These cars have "drop" bottoms, arranged in an ingenious way, so that the "rope rider" can readily open the bottoms and unload the coal into the hoppers in the long bin, under which the larry receives its coal for charging the coke ovens.

It may be observed that the mine cars are not unhitched at the hoppers; when emptied, they are let down into the mine, carrying the wire rope with them.

The coke is drawn in the usual way and loaded on large coke yard cars; from these it is dumped into the railroad cars at the lower ends of the ovens.

Although this plan of location impresses one at first sight as "ancient," yet it produces coke at moderate cost.

The prinicipal criticism that may be urged, is that the double handling of the coke into the yard and railroad cars, produce undue abrasion and breaking of the coke.

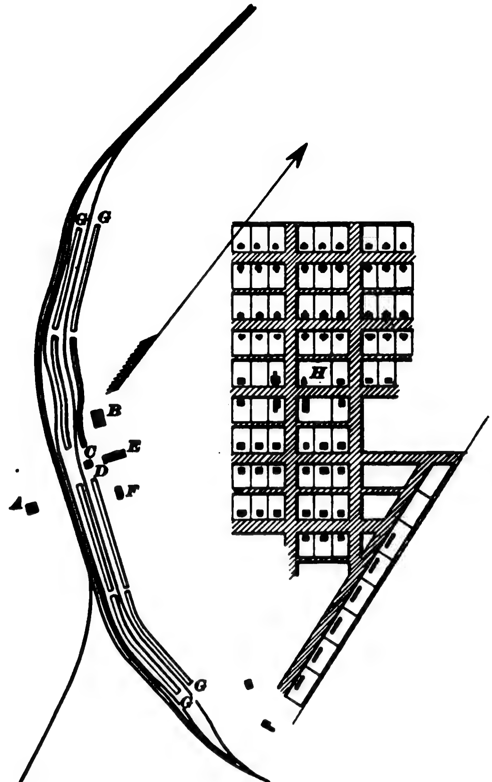


FIG. 80.—PLAN OF LEISENRING NO. 3 COKE PLANT.

Description.

A, Fan and Airshaft. *C*, Coal Bins. *E*, Engine, *G*, Coke Ovens.
B, Shops. *D*. Shaft. *F*, Boilers. *H*, Village.

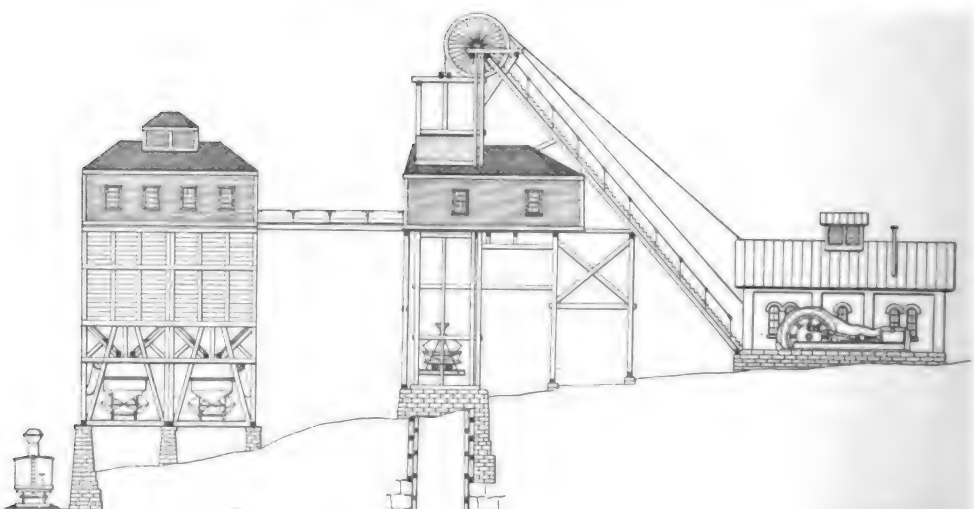


FIG. 81.—HEAD HOUSE AND BINS, LEISENRING NO. 3 COKE PLANT.

Fig. 80 will convey a correct conception of the general plan of location of the large coking plant, Leisenring No. 3.

It shows the outline of the plan of location of this plant of 500 coke ovens, in the Connellsville coke region.

Fig. 81 shows the elevations of the head-house and coal bins, for supplying these ovens with coal.*

These works were completed about the year 1887, by the original owners, The Connellsville Coke and Coal Company, E. B. Leisenring, President, and Mr. J. K. Taggart Superintendent and Engineer.

They are now owned and operated by The H. C. Frick Coke Company, Mr. Thomas Lynch, Gene al Manager.

It will be seen on Fig. 80 that these ovens were located in two curved wings on either side of the coal bin and shaft, up the gentle valley threaded by the Pennsylvania Railroad and the sidings for this large plant of coke ovens.

The ovens are charged in the usual way, a small locomotive is used in handling the coal larries to the several banks of ovens. This secures commendable despatch in this department of the work.

The wharves are ample, and the whole arrangements, for each division of labor, very complete.

The larry tracks are between the double rows of ovens. The side shutes to these charging larries can be seen on Fig. 81.

The elevation, showing details of head-house and bin, affords very complete details of these constructions for a central supply of coal for charging the ovens.

The only suggestion that occurs, on the line of security against fire at this plant, is, that the head-house, over the deep shaft, would be safer from the danger of fire if constructed mainly of iron.

The burning of a head-house causes immediate stoppage of the coke works, with interruption to coke shipments and serious financial loss.

A MODEL COKE PLANT.

Messrs. Wilkins and Davison, Engineers, Pittsburgh, Pa., have kindly furnished plans of the two very complete coking plants of the Messrs. Olivers, of Pittsburgh, located near Uniontown, in the Connellsville coke region. See Fig. 82.

* From the report of Mr. J. J. Davis, Inspector of Mines, Fifth Bituminous District, to Hon. Thomas J. Stewart, Secretary of Internal Affairs. Penna., 1888.

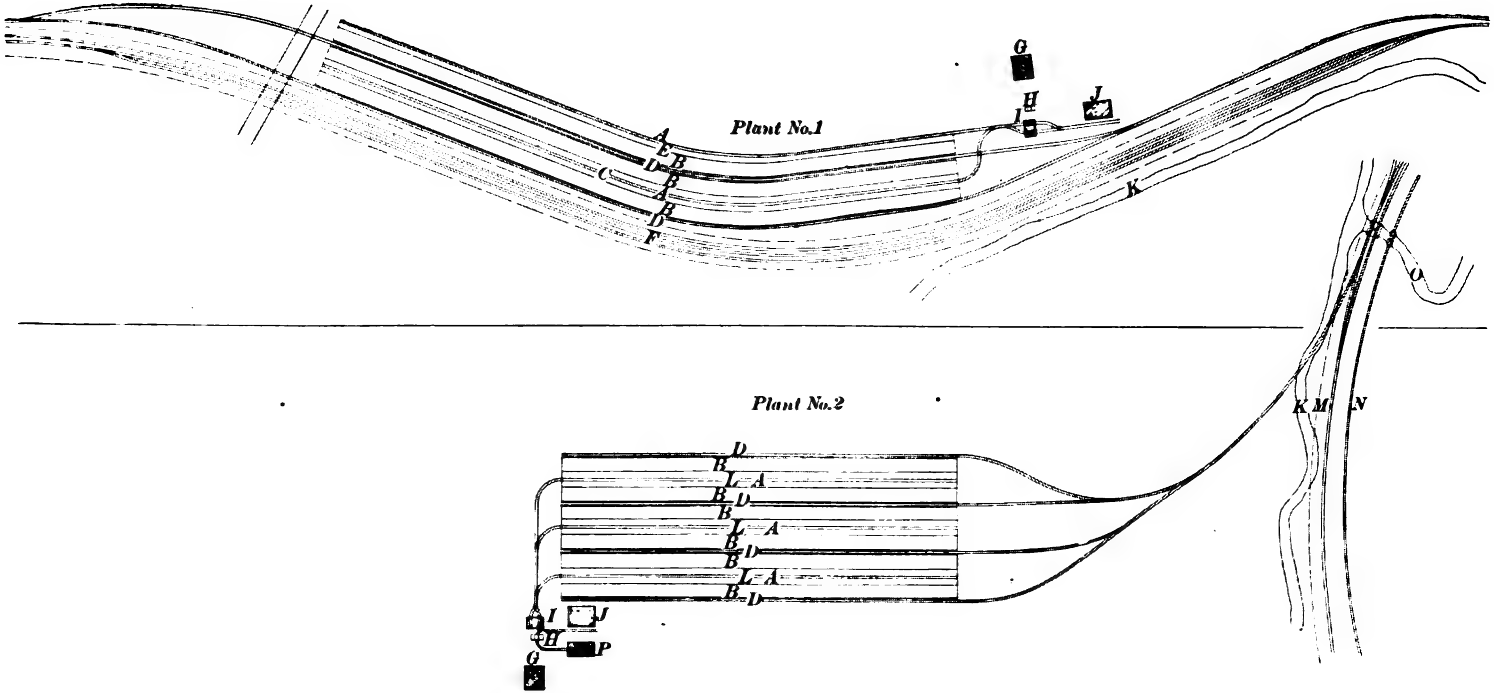


FIG. 82.—PLANS OF OLIVER COKE & FURNACE CO.'S COKE PLANTS, Nos. 1 AND 2.

A, Coke Ovens. *B*, Coke Yards. *C*, Block Ovens. *D*, Railroad Tracks. *E*, Bank Ovens. *F*, P. V. & C. R.R. *G*, Engine House. *H*, Shaft. *I*, Coal Bin. *J*, Boiler House. *K*, Creek. *L*, Block Ovens. *M*, S. W. Penna. R.R. *N*, B. & O. R.R. *O*, Creek. *P*, Blacksmith Shop.

Plant No. 1 consists of 300 Bee-Hive ovens, in two slightly curved lines, to conform to the topography of the ground, securing desirable gradients for railroad sidings and larry tracks. One of these banks of coke ovens is located in a line of single ovens 1,400 feet long, containing 100 ovens.

The second line, about the same length, consists of a bank of a double row of ovens, containing 200 ovens.

The railroad tracks and sidings are ample and well located to afford the necessary facilities for handling the output of coke. The ovens and railroad tracks are on gradients of one foot per hundred feet, descending with the tonnage. The ovens are 12 feet 3 inches in diameter.

This plant was completed early in 1892.

The locations of the shaft, engine house and coal bin can readily be seen on the plan. They were located to secure the utmost economy in the manufacture of coke.

Plant No. 2.—This plant has been located in three double banks of coke ovens. Each bank is 825 feet long and contains 120 coke ovens, making in all at this plant 360 ovens.

The *compact* location of these ovens, with the close relations of shaft and coal bins to the ovens evidence careful work in the plans.

The railroad sidings are well located for convenience. The railroad cars require some extra handling at this plant, as the railroad connections are confined to one end of the ovens.

The shafts, at these works, to the coal are about 415 feet deep.

With these deep shafts and the large daily supply of coal required from them for charging the ovens, it is evident that the head frames, coal storage bins and connections should be made of non-inflammable materials, to guard against serious and costly interruptions from fire.

FIG. 88.—VIEW OF HEAD HOUSE, COAL STORAGE BIN AND ENGINE HOUSE.

These conditions have been carefully secured at these works by constructing the head frames of shafts of steel, covered with corrugated iron. The coal storage bins have been constructed with similar materials and the engine houses of brick with iron roofs.

It is claimed that these fire-proof structures are the first of their kind introduced into the Connellsville coke region. This introduction, in the lines of safety to life and true economy in assuring continuous work, is very commendable.

The water supply is secured from the Youghiogheny river, ten miles distant.

The mining plans have been made by Mr. Fred. C. Keighley, who has had varied experience, as mine inspector of the Fifth Bitummous District of Pennsylvania.

The whole arrangements of these plants with their coal mines and bin storage supplies afford excellent examples of wise harmonies in securing economical and safe conditions to both the mines and coke ovens.

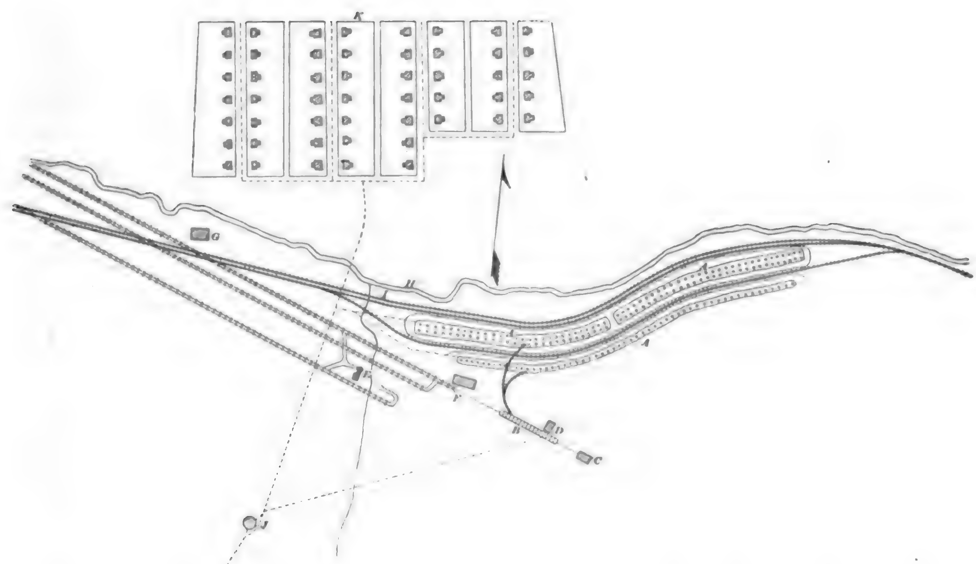


FIG. 84.—HOSTETTER COKE CO., LIPPINCOTT PLANT, CONNELLSVILLE REGION.

AAA, 305 Coke Ovens. *B*, Coal Hoppers. *C*, Hoisting Engine. *D*, Boilers. *E*, Fan. *F*, Slope. *G*, Store and Office. *H*, Creek. *I*, R.R. Siding. *K*, Workmen's Houses.

THE WORKS OF THE HOSTETTER CONNELLSVILLE COKE COMPANY.

These works consist of two coke plants, the Whitney and Lippincott.

They are located in the northern section of the Connellsville field, about one-half mile apart, on the Latrobe Branch of the main line of the Pennsylvania Railroad.

Both these works have been located in little valleys on small streams, tributaries of Nine Mile and Loyalhanna creeks.

They are very nearly alike in their plans of location and number of coke ovens. The method of location of the Lippincott plant will serve to illustrate the general plan of both these works. It has not been considered necessary to add the plan of the location of the Whitney works.

The Lippincott coke plant consists of 305 Bee-Hive coke ovens; these ovens are 12 feet in diameter and 7 feet high to crown of dome.

The ovens have been located in two lines, along the south bank of the Nine Mile Run, conforming in their alignment with the contour of the ground at this place.

The northern line of ovens is composed of a bank of a double row of ovens, the southern bank consists of a single line of ovens.

The plan exhibits the arrangement of the railroad tracks and sidings for the supply of coke cars for this trade. Ample room has been provided for storing empty coke cars at the upper or west end of the plant, with full space at the lower or east end for making up trains of loaded coke cars for transportation to market.

The coal cars are drawn up the slope from the mine by the winding engine and placed on the long coal bin, where they are unloaded rapidly into the hoppers underneath. The larries for charging the coke ovens are loaded under these hoppers.

The mine cars are not unhitched from the wire haulage cable, but are unloaded into this long bin by opening the bottom slides in these coal cars. A train of these loaded mine cars consists of ten cars, containing 45 bushels in each car—nearly 2 tons of coal.

Immediately on their being unloaded, they are quickly lowered into the mine, unhitched from the cable, which is then hitched to a loaded train of cars.

The larries for charging the coke ovens are handled by a seven-ton locomotive, operated on standard guage tracks.

The gradients of railroad and larry tracks descend eastward, affording nearly balanced gravity lines for these operations.

The office and store is located at the west end of the works, where the incoming and outgoing cars pass.

Arrangements have been made at both plants for shipping coal when found necessary to do so.

The slopes into the mines are 2,600 to 2,800 feet long. They have been driven in the large coal seam, which has here an inclination westward of 6½ feet per 100 feet.

These works were constructed during the years 1889–90, under the plans and supervision of Mr. John McFayden, the General Manager of the company.

Mr. Frank R. Boyd, of Uniontown, Pa., was the engineer in locating these works.

Mr. George J. Whitney, of Pittsburg, is President of the company.

When in full operation, these works can produce about 1,200 tons of coke per day.

The main effort in these locations, was, to *reduce the cost of the labor of making coke to a minimum.*

It is evident that this has been secured as far as the plan of extended oven lines would permit. It is worthy of future consideration in locating coke ovens, whether more compact lines, like those at Morrell and Oliver No. 2, would afford more labor ecomony in the section of the work in charging the ovens.

The engine and boiler houses are nearly fire-proof; they are isolated, so that the only danger from fire is in the long timber bins.

The water supply to all points is so well arranged and convenient, that it is hardly possible to incur a very serious fire.

The tenement houses are admirably located and quite comfortable. They are well supplied with water.

These double tenement houses are economical in the cost of construction, but it is evident that as a general rule the peace and quiet of each family would be better secured by single houses. In most, if not all cases, the tenants would willingly pay the extra rent to secure privacy and quietness in their homes.

THE RETORT OVEN PLANTS.

The following plan and elevation, Fig. 85, will show the general requirements in locating retort coke ovens:

It will be seen that the requirements in their location differ materially from the location of the Bee-Hive ovens, in the wider spaces demanded for the steam ram or pushing engine for discharging the coke from the retort ovens. In the above instance a width of 45 feet is required for steam connections and pushing engine.

In the Bee-Hive ovens, the coke is drawn out by manual labor, requiring only 30 feet of wharf room, whilst in the retort ovens 45 feet width in wharves is required on both sides of the ovens.

The plan shows the method of location of a bank of 20 Bernard coke ovens, with coal dump or hopper for receiving the coking coal from the mine or railroad cars, with elevators, disintegrator and storage tower; all in close relations to the bank of coke ovens.

The coal storage tower has double hoppers below, through which the coal is loaded into the charging larry.

The steam boilers are placed at the end of the bank of ovens, they are usually fixed by the gases from the coke ovens; but in case of failure of an

adequate supply of gas, the deficiency can readily be obtained in coal from the adjoining coal storage tower.

The space on wharf required for discharged coke is in this instance 40 feet wide to receive the charge of coke from the ovens, which is 30 feet long.

The bank of ovens can be extended to embrace a line of 60 coke ovens. When a greater number is required, parallel banks can be readily located.

If the by-products are to be saved, the necessary exhausting and condensing apparatus can be placed immediately behind the coal storage tower, in a building set apart for these uses.

In locating large plants of retort coke ovens in parallel banks, the exhausting and condensing appliances can be proportioned to supply two banks of 60 ovens each. A similar application can be made of the apparatus for treatment of coal, when it may be found necessary, that is, one apparatus to supply two banks of coke ovens.

In most cases it is considered prudent to establish duplicate condensing apparatus, as any interruption to this part of the work would produce general disorder.

Steam rams or pushing engines have been constructed under different plans. Some of these engines carry with them a steam boiler; whilst others receive their steam through ingenious arrangements of moveable steam pipes from stationary boilers.

Messrs. McLanahan & Stone, of Holidaysburg, Pa., have recently designed and constructed a somewhat new form of a coke pushing engine, one of which is now in successful use at the Semet-Solvay ovens, at the works of the Solvay Process Company, near Syracuse, New York.

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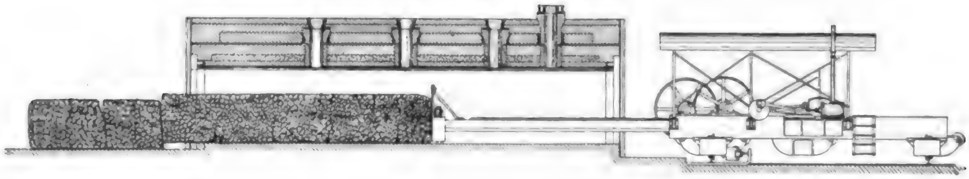

FIG. 86.—McLANAHAN & STONE'S STEAM RAM.

The section of this pushing engine and the Semet-Solvay oven will show the plan and operation of this machine.

The bracing of the pushing engine, by the curved rail track near ovens, is a novel feature in this appliance.

The gradients of railroad sidings and charging larry tracks should be governed by the same principles that are found necessary to economy of work in Bee-Hive ovens. In some cases the retort ovens are located in the immediate neighborhood of the blast furnaces, and the coke handled from the former to the latter in the usual coke barrows. Even in this location, gradients descending with the tonnage will conduce to facility and economy of this work.

In the foregoing considerations of the location of plants of coke ovens, the sites have been contemplated at or quite near the coal mines.

The usual quantity of coal to make one ton of coke is 1.4 to 1.6 tons.

The economy of locating coke works at the coal mines is based on the less freight charge on one ton of coke, against the charge on 1.4 or 1.6 tons of coal.

It is quite evident that in most cases this method of locating the coke ovens at the coal mines is the true policy. It has, however, some drawbacks. There is usually a loss of two or three per cent. in the loading of coke at the ovens and unloading it at the furnaces or steel works. In the wet and winter seasons it occasionally receives two to three per cent. of moisture in the transit.

But the loss in both of these would not compensate for the increased freight on coal to make coke at the furnaces or steel works, provided the freight charges per ton are equal.

But general rules have frequently exceptions. One of these exceptional cases has been developed by Mr. A. J. Moxham, President of The Johnson Company. In the planning of a large steel rail plant at Lorain. Ohio, he contemplates erecting a plant of retort coke ovens, with arrangements for saving the by-products of tar and ammonia sulphate in coking.

The coal for coke making will be shipped from the Connellsville region, or such other localities as may be found to afford good coal for the manufacture of coke.

This will secure the maximum economies in the production of a fresh dry coke, without the usual waste by abrasion in handling. The value of the saved by-products will assure a first class quality of coke at a moderate cost.

This economy in coke making at the Lorain works is aided in part by the lower freight rates of coal to this point, as compared with the increased rates charged on the transportation of the bulkier coke product.

CHAPTER IX.

GENERAL CONCLUSIONS ON THE WORK, COST AND PRODUCTS OF THE SEVERAL TYPES OF COKE OVENS.

Areas of the Several Qualities of Coking Coals.—Section I.: The Rich Bituminous Coals, West.—Section II.: The Connellsville and West Virginia.—Section III.: The Medium Qualities of Coking Coals.—Section IV.: The Very "Dry" Coking Coals. —Exceptional Belt at Johnstown, Pa.—The Narrow or Retort Coke Oven for III. and IV. Coals.—Results of Coking Tioga Coal in Bee-Hive and Semet-Solvay.—Resistance of these Cokes to Dissolving Action of CO_2.—Resistance of Connellsville Coke and Anthracite Coal.—Geological Map-line of Eastern Boundary of Appalachian Field.—Selecting Coal for Coking.—Comparison of Economies in Cost and Results.—Best Coking Coal under Largest Cost, Most Economical.—General Table I.—Exhibiting the Cost and Working of the Several Types of Coke Ovens in Detail.—Value of By-products, Per Ton of Coke made.—Full Explanation of the Several Sections of Table.—Difficulty of Reconciling Costs of Ovens and Value of By-products.—Dimensions of Retort Ovens.—Sizes of Coking Chambers.—Proportion of Daily Product of Coke to Size.—Calculating Ultimate Cost of Making one Ton of Coke.—Review of Physical Properties of Coke made in Each Type of Oven. —On Selecting Special Type of Oven for the Several Varieties of Coals.—Dr. Terne on Waste of By-products in United States.—Plan for Saving By-products in Bee-Hive Oven.—Quality of Retort Coke.—Considerations involved in Adopting a By-product Plant.—Average Value of By-products Per Ton of Coke made.—Table of Imports of Pitch and Tar, 1892–1893.—Tar made in United States, 1893.—Imports of Fertilizing Elements, 1893.—Dr. Wagner on Value of Fertilizers in Agriculture. —Market for Ammonia Sulphate assured.—Chêmical Works and Tar Boiling Plants.—Investigation of Disposition of By-products in Crude State.—Analyses of Ammonia Sulphate.—Tabular Statement showing the Cost of its Manufacture.—Economy of Treating By-products.—Small Works sell Crude Products.—Large Works advance Them to Pitch and Ammonia Sulphate.—Benzole as a Gas Enricher.—Its Value if This proves Practical.

In the eastern and middle coal fields of the United States, the areas of the sections of the coal measures whose beds are adapted for the manufacture of coke, in greater and less degrees, have been generally well defined.

Much has yet to be done in the great far west in the further development of its coal fields, and in determining the special localities affording coal suitable for making coke.

So far as our present knowledge extends, there are at present four well known groups or sections of coking coals.

These areas of coking coals are found in meridional strips, conforming in their general southwestward courses to the crest-line trends of the Appalachian mountain chains. They are found in the following order from west to east:

SECTION I.—The several types of coals very rich in bituminous matter, affording a light coke with a highly inflated physical structure, and not regarded as a desireable fuel for metallurgical purposes.

This class of coals contains from 35 to 40 per cent. of volatile matter.

Some efforts have been made in coking these coals. Evidently the progress thus far has not been quite satisfactory. Treatment in the horizontal types of ovens appears to have produced the best results; but the coke is usually spongy, inheriting an inflated physical structure and lacking the hardness of body so essential to a good metallurgical fuel.

It is coming to be understood that this class of rich bituminous coals require a moderate oven heat in securing the best possible coke from such coal.

A broad horizontal oven, with flues under its floor, heated with returned gas evolved in coking, and without side flues, would probably be the best method of reducing the injurious action of the surplus fusing matter in these coals. This would be a somewhat different application of the meiler or mound principle of coking coal.

It is probable that a mixture of the class of "dry" coking coals, with these rich bituminous coals, would produce a firm coke. This, however, would involve the additional expenses of freight, with extra care and labor in mixing the coals.

It is important to note that the area of this section of rich bituminous coal is by far the largest, in fact larger than all the others together. It follows, therefore, that it presents an inviting field for further experiment in determining the best type of coke oven for the sucessful production of useful coke in this large area of bituminous coal.

A serious difficulty has embarrassed the efforts hitherto made to produce clean metallurgical coke from these coals, from the rather large percentage of sulphur inherited by most of these coals.

This sulphur is found generally interleaved in the bedding planes of the coal, as well as scattered through it in thin scales. The attenuated condition of this sulphur admixture constitutes the chief difficulty in efforts to reduce or remove it by the ordinary processes of disintegration and washing.

A practical plan for reducing this thinly mingled sulphur from these western coals would enable a coke to be made from them that could be used in whole or in part in blast furnace operations.

The type of coke oven to produce the best possible coke, with the saving of by-products, would evidently follow promptly the success of cleansing the coal for the manufacture of coke.

SECTION II.—This small section embraces the best qualities of coals for the manufacture of coke. They contain 25 to 35 per cent. of volatile matter. The strip is narrow, averaging three to five miles wide in southwestern Pennsylvania, located parallel to and west of the Chestnut Ridge. It constitutes the celebrated Connellsville coke region. It extends through West Virginia, inheriting in that State a slightly increased volume of bituminous matter.

The cokes made from these coals are firmly established as regards purity and calorific energy in all metallurgical operations.

SECTION III.—This section, consisting of the dryer qualities of coking coals, is next in magnitude to Section I and only secondary in quality to Section No. II. These coals, under careful oven treatment, afford good coke; they contain 20 to 25 per cent. of volatile combustible matter.

This strip is located in Pennsylvania, Maryland and the Virginias. It is situate along the inner eastern border of the Appalachian field.

Its coal can be coked in horizontal ovens with fairly good results; but, with some exceptions, it does not usually inherit the hardness of body and calorific energy of the cokes from Section II.

It is quite evident that the vertical types of coke ovens are best adapted for the production of the best coke from this family of coals, as they confer on it the essential physical property, hardness of body, which assures its value as a blast furnace fuel.

They would also afford an increased percentage of coke from these rather "dry" coals as compared with the horizontal type of coke ovens.

It is also evident that in using the vertical or retort coke oven, in making coke from these coals, the plant should be provided with the necessary apparatus for saving the by-products of tar and ammonia sulphate, as the profits from these will be found helpful in supplementing the small income from the coke.

As it is now becoming evident that the comparatively limited areas of the best coking coals are being rapidly exhausted, the question of providing the best means of manufacturing coke from the dry coals is a pressing one, deserving the earnest consideration of those coke producers who may be required to use this class of coals.

As the region of the first-class coking coals becomes more reduced in area on the one side, with the growth or expansion of the use of coke on the other, it follows that the increase of coke demanded by the iron and steel manufacturers must be supplied mainly from the coals of Section III.

Some investigations and tests have been made in the use of retort ovens in coking these coals, which so far have afforded assurance of satisfactory results.

The chief difficulties retarding this movement in the introduction of vertical coke ovens consist in the large capital required in establishing a retort coke oven and by-product plant, with the additional expense in preparing the coal for the coke ovens.

From the cost of mining, the smaller coal beds of this section, with further cleansing when needed, would carry to the coke about 34 to 41 cents per net ton in vertical ovens, and 40 to 48 cents per ton in horizontal ovens.

Some compensation is afforded in this locality in the reduced railroad freight eastward.

SECTION IV.—The coals embraced in this section are very "dry," holding only 15 to 20 per cent. of volatile combustible matter, and requiring special oven treatment.

It is situated mainly along the eastern border of the Appalachian field, from northern Pennsylvania to southern Virginia. It has several outlying and detached fields, such as the Blossburg, Lycoming, Broad Top, Cumberland, etc., etc.

There are some notable additions to the outer edge "dry" coals. One of these is found at Johnstown, Pennsylvania, where the coals contain only 16 to 19 per cent. of volatile matter; and although located in the III section of medium coking coals they really belong to the IV section of "dry" coals.

From its geographical position westward its coal should inherit at least 25 per cent. of volatile matter, but it is a remarkable fact that a broad belt of this exceptional "dry" coal is found in this inner section of the Appalachian field.

Its extremities northeast and southwest have not been defined.

For the proper treatment of this section of extremely dry coals *the narrow vertical oven must be used.*

The coal will also, in most instances, require preparation by disintegration, in separating slates and pyrites, and in many cases by washing.

In this connection a very marked example of the effects of coking Blossburg coal in Bee-Hive and Semet-Solvay ovens has come to notice.

In the round oven this "dry" coal affords 61 per cent. of marketable coke. In the Semet-Solvay oven it yields 78 per cent. of large coke.

Samples of each were tested in the laboratory for resistance to hot carbon dioxide. A few grains of each were placed in a test tube, and submitted to the action of a stream of hot carbonic acid gas, for equal periods of time, with the following results:

	CO_2.	CO.
Semet-Solvay	88.8	11.2
Blossburg	65.4	34.6

These tests indicate the very wide difference in the hardness of the body of the coke and its property of resisting the dissolving agency of carbon dioxide, such as would be encountered in a blast furnace.

The CO column shows more than three times the probable loss in the horizontal oven coke above the Semet-Solvay oven coke.

The difference in product in these ovens is quite large, the vertical oven affording an increase of 17 units of coke, or 22 per cent. increase in product over the Bee-Hive oven. This increase contributes to the reduction of the volume of impurities to the sum total of the coke.

It may therefore be accepted as a general principle in the treatment of these "dry" coals, *that the quick and superior heat in the retort ovens produces the hardest bodied coke with an increased quantity of it.*

The Connellsville coke made in Bee-Hive and Otto-Hoffman ovens gave, from a similar test, the following results:

	CO_2.	CO.
Bee-Hive Connellsville coke	91.0	9.0
Otto-Hoffman	94.5	5.5

As a standard for comparison, anthracite coal, which is a natural coke, gave the following result:

	CO_2.	CO.
Anthracite coal	96.0	4.0

The Connellsville coke made in Bee-Hive ovens, as well as the portion made in Otto-Hoffman ovens, is best qualified by hardness of body to resist destructive dissolution in blast furnace operations. This assures the economy of fuel per ton of pig iron made, and the further advantage of increased output.

In the West, the newer coal deposits afford occasional areas of good coking coals. The States of Colorado and Wyoming have shown considerable progress in the production of good qualities of metallurgical cokes.

The gradual de-bituminization of the coals eastward, has been noticed very fully in Chapter I.

An examination of the geological map will show the general contour of the eastern edge of the great Appalachian coal field. It will be noted that this eastern contour line maintains a certain parallelism with the old time Atlantic shore line of this portion of the North American Continent.

The intense dynamic thrust westward, in the States of Kentucky, Tennessee and Alabama, with the subsequent erosion along their eastern border, has removed the region of the "dry" coals, and conferred on their remaining coals a medium quality between the bituminous coals of the West, and the dry coals on the eastern borders.

With these well defined areas of coals that can be coked, the coke manufacturer can decide three important conditions in selecting a location for his plant: 1st. In which of these sections will he establish his coking plant? 2d. What type of coke oven will be best adapted to producing the best possible metallurgical coke? and 3d. Will it be profitable in making coke to save the by-products, the tar and ammonia sulphate?

It may be helpful in determining the location of the coke plant, with the type of oven to be used, to submit the following considerations:

1st. If possible the manufacturer of coke should locate his plant in the best coking coal belt.

This assures the best product of coke, and removes any suspicions as to its quality; to be liable to be called upon to defend the character of coke made in localities not well known or not having the quality of its coke assured, adds considerable worry to the duties of the manufacturer.

It will be found, on careful consideration, that the difference in the price per acre is not a vital element of discouragement in shaping a decision. For instance, the best coking coal land costs now $600 to $1,000 per acre. An acre of this coal bed, 7½ feet thick, will afford an output, with careful mining, of 12,000 net tons of coal.

The mining of this coal, under existing conditions in the Connellsville field, costs about 20 cents per net ton.

The coal requires no disintegration or washing.

The royalty on coal, at $1000 per acre, is	$0.0833	per net ton.
Mining Coal	0.2000	" "
Total	$0.2833	" "

Second class coking coal can be purchased for $50 per acre for the coal bed alone. Assuming the thickness to be the same, 7½ feet, affording 12,000 net tons of coal per acre, the cost will be as follows:

Royalty on Coal	$0.00416	per net ton.
Mining	0.40000	" "
Total	$0.40416	

The difference is $0.12086 per net ton or $1450.32 per acre in favor of the first quality. But the difference in cost is $950, against the best coal, having still in its favor $500.32 per acre, to cover interest on the increased investment.

Again, supposing the second quality of coking coal requires disintegrating and washing, this will add 5 to 8 cents per ton usually, or at least $600 per acre—making the ultimate difference, in this case, equal to $1,100.32 in favor of best quality of coking coal. It is, therefore, evident that the best qualities of coking coals, commanding the higher price, are under full consideration the cheapest in the end.

In the thin beds of the III section of coals the difference in ultimate cost would be still greater, as the increased cost of mining and mine ways would have to be considered.

In the selection of coke ovens for coking the several qualities of coals, the following general tabulated statement, approximating the cost and work of each type of oven, will be found helpful.

TABLE EXHIBITING THE RELATIVE ULTIMATE ECONOMY OF PLANTS OF TYPICAL COKE OVENS—SINKING INVESTMENT IN 20 YEARS.

Name of Oven.	Cost per Oven.	Cost of Condensing Plant per Oven.	Total Cost per Oven.	Daily Output per Oven.	Number of Ovens to make 118,800 Tons per Year.	Total Cost of Plant.	Maintenance and Repairs 5% per Year on Investment.	M. & R. per Ton of Coke.	Sinking Plant, 20 Years, per Ton Coke.	Labor Making Coke and Saving By-products.	Total Cost per Net Ton.	Per Cent. Coke Made.	Value of Units of of Coke over 65%.	Value of By-products per Ton Coke.	Ultimate Cost per Net Ton.	Remarks.
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	
Bee-Hive	$300	....	$300	2.00	198	$59,400	$2,970	$0.02½	$0.02½	$0.32	$0.37	65	....	....	$0.37	Not saving by-products.
Thomas	800	....	800	3.9	102	81,600	4,080	0.03⅓	0.03⅓	0.27	0.33⅔	65	....	....	0.33⅔	" "
McLanahan	800	....	800	3.0	132	105,600	5,280	0.04½	0.04½	0.25	0.34	65	....	....	0.34	" "
Belgian	1,000	....	1,000	2.7	147	147,000	7,350	0.06⅛	0.06⅛	0.25	0.37¼	70	0.06¼	....	0.31	" "
Coppée	1,000	....	1,000	2.3	172	172,000	8,600	0.07¼	0.07¼	0.25	0.39½	72	0.08¾	....	0.30½	" "
Bernard	1,000	....	1,000	2.3	172	172,000	8,600	0.07¼	0.07¼	0.23	0.37½	75	0.12½	....	0.25	" "
Simon-Carvès	1,300	1,000	2,300	2.3	172	395,600	19,780	0.16⅝	0.16⅝	0.40	0.73⅛	75	0.12½	0.35	0.25⅝	Saving by-products.
Semet-Solvay	1,600	1,700	3,300	4.0	99	326,700	16,335	0.13¾	0.13¾	0.40	0.67½	75	0.12½	0.35	0.19⅛	" "
Hüessner	1,400	1,500	2,900	3 2	124	359,600	17,980	0.15⅛	0.15⅛	0.40	0.70⅛	75	0.12½	0.35	0.22⅝	" "
G. Seibel	1,300	1,500	2,800	3.3	120	336,000	16,800	0.14¼	0.14¼	0.40	0.68⅛	75	0.12½	0.35	0.21	" "
Otto-Hoffman	1,600	1,700	3,300	3.3	120	396,000	19,800	0.16⅔	0.16⅝	0.40	0 73⅛	75	0.12½	0.35	0 26 1/12	" "
Festner-Hoffman	1,500	1,600	3,100	3.2	124	384,400	19,220	0.16⅛	0.16⅛	0 40	0.72⅛	75	0.12½	0.35	0.24⅝	" "

NOTE.—The value of ammoniacal liquor to make 1 ton of ammonia sulphate is estimated at $15.00 for 2° T. liquor at coke ovens. The tar is valued at $5.00 per ton at ovens. It is estimated that in coking 100 tons of coke, 1 ton of ammonia sulphate and 3 tons of tar will be saved. Surplus heat from ovens is included in ultimate saving. Ammonia sulphate, $55.00 per ton in market.

It may be submitted, in explanation of the foregoing table, that the comparative standard of annual production, in marketable coke, has been fixed at 118,800 net tons. This is about the yearly product of two banks of Otto-Hoffman coke ovens of 60 ovens each.

Column *a* gives the estimated costs of these coke ovens. Column *b* shows the cost, per oven, of the exhaust, condensing and scrubbing plant.

Column *c* gives the total cost, per oven, including where used, the by-products saving plant.

Column *d* gives the average daily product of marketable coke from each type of coke oven.

Column *e* gives the number of each kind of oven to produce 118,800 net tons of coke per year.

Column *f* gives the total cost of each coking plant and *g* shows the amount of labor and materials to maintain the works in good condition, estimated at 5 per cent. on investment. This charge is designed to afford a fund to make the necessary repairs during the 20 years' life of the plant.

Column *h* distributes this interest sum over each ton of coke made.

Column *i* exhibits the proportion of the cost of sinking the whole plant in 20 years. It is estimated that, during this period, 2,376,000 net tons of coke shall have been made.

The cost of *labor* in making coke and in making coke and saving the by-products is given in column *j*.

Column *k* shows the total cost per net ton of coke made, it embraces the costs in columns *h*, *i* and *j*.

The percentage of coke which each type of oven produces is given in column *l*.

Column *m* exhibits the value of the units of coke made in the several ovens over the Bee-Hive 65 per cent. standard.

The value of the by-products of tar, ammoniacal liquor or sulphate of ammonia, is given in column *n*. This value is considerably under the usual sums estimated for these products. But it is submitted that the value of by-products *at the works* and in a more or less distant market, differs materially. It may also be noted that these products have, in common with all others, their variations in market value.

The ultimate cost, per net ton of coke produced, is given in column *o*.

In all the calculations it has been assumed that the best coking coals have been used. No charges have been made for the preparation of coals that require crushing and washing.

No *patent right charges* have been embraced in these columns.

In making the foregoing comparisons, no credit has been given the retort ovens for heat supplied for making steam, or for surplus gas for lighting purposes. They have received, however, credit for increased percentage of coke produced over the standard or Bee-Hive oven.

As has been noticed, the fact has not been established, whether this increased output of these ovens will produce, in metallurgical operations, a corresponding proportional increase in calorific energy.

The costs of repairs in these typical ovens have been considered equal, per net ton of coke made.

It has been found quite difficult to reconcile the reports of the costs and values of by-products in these ovens. The claims for their several merits, usually advanced by authorities friendly to special ovens, have generally been found to exhibit their best qualities, and to withhold elements that would tend to shadow their values.

The cost of the *coke oven* with the *cost of its share* of the apparatus for saving the by-products, are usually given from the account book statements in Germany, France and England. The cost of labor in the United States of America, will in all cases exceed the costs in these countries quite largely.

Much care has been given to adjusting these costs for the average of the United States. It may be noted that these costs, as given in the table, are quite liberal.

There are quite large differences in the daily output of coke from these ovens.

It appears that the hot ovens afford the larger daily products. The Semet-Solvay, the Otto-Hoffman and the Festner-Hoffman, the Hüessner and Seibel are examples in point.

This assumes that the sizes of the coking chambers of these ovens are all equal, which is not quite correct, as the following comparisons will show:

Simon-Carvès...	23	feet	long.	20	inches	wide.	6	feet	6	inches high.
Semet-Solvay ...	30	"	"	16½	"	"	5	"	6	" "
Hüssner	29	" 6⅜"	"	22⅝	"	"	5	"	7⅞	" "
G. Seibel........	29	" $6\frac{5}{16}$"	"	23⅝	"	"	5	"	10⅞	" "
Otto-Hoffman...	33	"	"	20	"	"	5	"	3	" "
Festner-Hoffman	29½	"	"	23	"	"	5	"	11	" "

Calculating the cubical contents of the coking chamber of each oven, the following table will exhibit the relations of capacity to output:

TABLE SHOWING CAPACITY AND OUTPUT OF OVENS.

Name of Oven.	Cubic Feet in Coking Chamber.	Percentage Capacity.	Actual Daily Product. Net Tons.	Daily Output in Protion to Cubic Contents. Net Tons.
Simon-Carvès	249	15.1	2.3	2.90—
Semet-Solvay	227	13.8	4.0	2.65+
Hüessner	314	19.0	3.2	3.69—
G. Seibel	242	14.7	3.3	2.82+
Otto-Hoffman	287	17.4	3.3	3.35—
Festner-Hoffman	334	20.0	3.2	3.90—

The average actual daily product of coke, per oven, is 0.0116 net ton per cubic foot of oven chamber space.

From the above table it will be seen that the Semet-Solvay and the G. Seibel ovens afford daily outputs in excess of requirements of the cubic contents of their coking chambers. The other ovens fall somewhat short of it.

The entire cost of coke made in these ovens can readily be ascertained by taking the percentage of marketable coke produced by each type of oven, as given in column 7. For instance, the Bee-Hive oven yields 65% of coke: it will, therefore, require $\frac{100}{65} = 1.538$ tons of coal to make one ton of coke. The cost of the coal, delivered at the coke ovens, can readily be learned for any locality.

The ultimate cost in column *o*, added to the cost of the amount of coal to make one ton of coke, will give the absolute net cost of one net ton of coke.

In the areas of the best coking coals, the horizontal types of coke ovens will probably retain their places of usefulness. The principles involved in the manufacture of metallurgical coke in these ovens are undoubtedly the true ones, concentrating the greatest heat at the crown of the oven and graduating it downwards towards the bottom of the oven. This secures, under the moderate pressure of the charge of coal, the liberty or freedom of the mass to develop cell structure and secures the deposit of a maximum quantity of carbon from the gases evolved in coking as they pass upward through the incandescent portion of the charge, glazing it with this deposit of pure carbon.

It is evident that the floors of these types of ovens should be without flues. If these are introduced they will result in disarranging the regular process of coking downwards, from the upper surface of the charge of coal to the floor of the oven, and neutralize, in part, its good results by producing a stratum of ill-coked coal where the two operations meet in the charge of coal in the oven.

The manual labor in drawing the round ovens should be removed, it is exhausting to the workmen and expensive to the manufacturer.

The by-products of tar and ammonia should be saved and the gases, deprived of these, returned to reinforce the heat of the oven.

The vertical or narrow ovens will come into use gradually, as the best qualities of coking coals become reduced in area, compelling the coking of the second quality of coking coals.

In the determination of the quality of coal for the manufacture of coke, the sure method is to have a sufficient quantity of it coked carefully in one or more selected types of coke ovens. The physical properties of the coke, as well as its calorific value for blast furnace use, can be accurately ascertained by laboratory tests.

In selecting the type of oven for coking any of the several qualities of coal, it will be well directed economy to have this work performed under the care of an expert in the manufacture of coke; as not only the type of oven is to be selected as best adapted for coking the coal, but the proper dimensions of the several parts of the oven chosen are to be determined.

Attention is invited to the ingenious plant of Dr. Otto for obtaining the by-products from the Bee-Hive type of horizontal ovens. Dr. Terne in his paper calls earnest attention to the large waste, in the United States, of this valuable manure in the manufacture of coke. With the 42,000 of these ovens now in operation, a large field is invitingly opened to inventors to devise a practical plan for saving these by-products and augmenting the oven heat by the returned gas.

The products of Dr. Otto's round oven are shown to be equal to any of the retort ovens, 75 per cent. coke, 1 per cent. ammonia sulphate and 2½ to 3 per cent. of tar.

The cost of this oven has not been given. From its plain construction this cost would be small as compared with the vertical ovens.

An important supplementary consideration for the coke manufacturer is presented in the question, in connection with the use of retort coke ovens, whether it will be profitable to invest the large additional sum required in the conduits and condensing plant for the saving of the by-products of tar and sulphate of ammonia.

The approximate cost of the auxiliary plant for saving these by-products is given in table on page 274.

In approaching this inquiry, it may be submitted, that hitherto considerable prejudice has been manifested against the quality of coke made in retort coke ovens, in which the by-products were saved.

Sufficient evidence has not been developed in this country to settle this matter by accurate tests in blast furnace use, but on the continent of Europe it is alleged that at present no discrimination is made by metallurgists against this quality of the retort coke oven, provided it is made in a careful manner.

There does not appear any evident reason why the exhausting of the gases in coking should deteriorate in a marked degree the quality of the coke, but it should on the other side, by increasing its hardness, more than compensate for any loss in the exhaustion of the gases.

The question then reverts to the amount of the investment in the additional appliances and plant for saving the by-products and the probable revenue from the sale of the same.

Taking, as an example, a coking plant of an annual capacity of 118,800 net tons of coke. The average cost of a condensing plant for 120 coke ovens, at $1,600 per oven, would be $192,000. The yearly interest on this sum at 10 per cent. would be $19,200. The value of the by-products, at a very careful estimate, is given at 35 cents per ton of coke produced, affording an annual income of $41,580. Deducting the interest on the investment in the condensing plant, leaves of profit $22,380. Now, if the further charge of sinking the condensing plant in 20 years is considered, the yearly reduction will be $9,600, which deducted from $22,380 leaves $12,780, as a clear profit from saving the by-products, or 6.65 per cent. on the cost of the condensing plant.

Another consideration is pertinent here, touching the permanency of the market for these by-products of tar and ammoniacal liquors.

The following table will exhibit the imports of coal tar in various forms for the fiscal years of 1892 and 1893:

TABLE OF IMPORTS OF TAR AND AMMONIA DURING THE FISCAL YEARS OF 1892 AND 1893.

From the Bureau of Statistics, Treasury Department.

ELEMENTS.	Unit of Quantity.	Quantities.		Values.		Value Per Unit.		Duties.		Ultimate Cost Per Unit.		REMARKS.
		1892.	1893.	1892.	1893.	1892.	1893.	1892.	1893.	1892.	1893.	
Coal Tar, Pitch of Coal Tar......	Barrels.	117,056	102,135½	$ 302,791.05	$ 244,291.00	$2.58	$2.39	....	....	$2.58	$2.39	No Duties or Tax.
Tar and Pitch of Wood..........	"	768	1,179	3,352.00	6,376.00	4.36	5.41	....	....	4.36	5.41	" " "
Burgundy Pitch................	"	5,628¾	4,134¾	4,386.00	3,558.00	8.00	8.50	....	....	8.00	8.50	" " "
Coal Tar, Unclassified...........	"	....	....	42,827.26	158,713.04	....	....	20%	20%	....	....	20% Ad Valorem.
Totals......................	"	123,452¾	107,459¼	$ 353,356.31	$ 412,938.04	....	....	....	....	....	....	
Ammoniacal Liquors........	Pounds.	....	....	$ 3,136.00	$ 718.00	....	....	20%	20%	....	....	20% Ad Valorem.
Carbonate of Ammonia..........	"	490,699	551,824	32,518.00	36,352.00	....	$0.066	26.41%	26.56%	....	$0.083	" " "
Muriate of Ammonia.....	"	3,878,073	4,217,025	203,671.62	208,068.00	....	0.049	14.28%	15.20%	....	0.056	" " "
Sulphate of Ammonia	"	9,906,590	14,025,750	236,085.00	315,802.00	....	0.023	20.98%	22.21%	....	0.045	" " "
Totals......................	"	14,275,362	18,794,599	$ 475,410.62	$ 560,940.00	....	$0.0298	....	....	....	0.03575	" " "

NOTE.—The amount of Tar imported during the fiscal year 1893 was 41,500 tons. Tar produced in the United States, mainly from gas works, is approximated by Dr. Slocum at 175,000 tons. This exhibits the use of 216,500 tons during this fiscal year.

The ammonia products in 1893 show a large increase in imports, aggregating in all 9,397¼ tons, at an average cost of $71.47 per net ton.

There were also imported 124,216 net tons of fertilizing substances, costing $1,221,104.73, an average of $9.83 per net ton. These were used mainly for manures. The importation of nitrates is quite large, amounting to 113,899 net tons, costing $3,673,333.00, or $32.25 per net ton. How much of this importation was used for fertilizer is not defined. The native phosphates during 1893 amounted to 941,368 gross tons, valued at $4,136,070.00

From this statement it will be seen that the imports of coal tar in different conditions amounted to 41,500 net tons during the fiscal year 1893.

During the same year it is estimated that there were produced in the United States, mainly from gas works, 175,000 tons, exhibiting the use of 216,500 tons during the year.

The 45,000 coke ovens now in use in the United States producing 10,000,000 tons of coke yearly are mainly non-producers of by-products. If all were equipped to save the by-products, there would be thrown on the market 300,000 tons of tar and 100,000 tons of ammonia sulphate annually, with increase as the coke ovens would be increased in number. But it is not probable that many of the primitive ovens will be equipped to save the by-products at an early date; not certainly for many years to come.

It is evident, therefore, that there is at this time a home market for an additional quantity of at least 100,000 tons of tar, which will be increased with the growth of its use in many industries and under the decreasing product of the coal gas works, as many of these are changing the method of manufacturing illuminating and heating gas from coal to coke in producing water gas.

This weakening of the market for tar would probably cause the gas works using coal to go over to the water gas method, as the by product of tar would become unprofitable.

It can be said that whilst the present market for the by-products of tar is fairly well assured, yet it is evident that with the introduction of several large plants of retort coke ovens, saving the by-products, the demand would be seriously weakened.

It has been suggested that it could be used as a fuel for generating steam and for heating purposes. It has been so used in these ways, but the difficulties in its application, especially in the winter season, are so formidable as to exclude it from general use, especially in the large sections of the United States in which coal is so abundant and cheap.

The market for the twin by-product in the manufacture of coke, ammonia sulphate, rests upon a more substantial foundation; as its chief use as a fertilizer assures a large and increasing demand for agricultural purposes. This will be emphasized when the large imports of fertilizing substances, during the fiscal year 1893, are considered.

During this year there were imported into the United States, the following substances, mainly for fertilizing uses:

	Tons.	Value.
Guano	5,856	$97,889.00
Crude Phosphates, etc	106,549	816,760.00
South American Nitrates	113,899	3,673,838.00
English Ammonia Sulphate	9,398	690,753.00
Totals	235,702	$5,279,240.00

The amount of ammonia sulphate produced in the United States, during the fiscal year 1893, has not come under the notice of the writer. Assuming that the average relations of this salt to the tar, 1:3, has been secured, it would afford 58,333⅓ tons for fertilizing and other purposes, showing the approximate consumption in the United States during the year of 67,731⅓ tons.

Mr. Wagner, of Darmstadt, has recently shown that ammonia sulphate is superior to Chili saltpeter or guano as a fertilizer in agricultural uses.

In the United States, there are approximately 300 millions of acres of land under cultivation.

Perhaps one-third of these retain much of the normal richness and will not at present require concentrated manures.

It is further assumed that one-third will be manured in the usual way with barnyard and compost manures, and that 50 millions of acres will be manured by native and imported guano, phosphates, nitrates and ammonia sulphate, leaving 50 millions of acres to be supplied mainly by native ammonia sulphate. This will require 160 pounds of this salt or its equivalent to fertilize one acre in an ample manner. For the 50 millions of acres, 4 millions of tons of this manure will be required, but it is not probable that this will be used by the agriculturists for some time to come.

Reducing the probable quantity of this concentrated manure that may be required to 2 millions of tons per year, it will readily appear that the product of ammonia sulphate, during the year 1893, did not greatly exceed 60,000 tons, leaving 1,940,000 tons to be provided for. Should the coke ovens of the United States be changed to save this by-product, from the 10 millions of tons of coke, it would afford 1 million of tons of ammonia sulphate, leaving a deficit of 940,000 tons.

The outlook for a market for ammonia sulphate is well assured. It may be noted, however, that in competition with other manures its price will be held at a maximum not greatly exceeding 3 cents per pound.

The chemical works and tar distilleries at Philadelphia, Buffalo, Cleveland and Chicago are prepared to purchase tar and ammoniacal liquor.

These companies usually own and furnish iron tank cars for freighting these liquid products from the coke works to the chemical plants.

Some of the companies are prepared to receive the tar during all the months of the year; others require the coke manufacturer to store the tar in great tanks during the winter months.

It becomes an important consideration, in this connection, how far the coke manufacturer should advance these distillates in order to secure the maximum profit from their sale in market.

It is evident that tar, as it is condensed from the gases at the coke ovens, can be shipped with the most economy in its crude state, provided it can be marketed continuously throughout the year. Boiling it to pitch involves extended chemical operations, in securing the utmost economy, by saving the light oils evolved in pitch boiling.

A companion investigation relates as to whether the coke manufacturer will dispose of the ammoniacal liquor, at the strength usually required, 2°, 2.5° and 2.8° Twaddell, or advance it to ammonia sulphate, either as an agricultural manure or for chemical uses.

The latter involves an ammonia factory addition to the condensing plant, with expert chemical supervison.

If the market or chemical works is not at a great distance from the coke works, it would in most cases conduce to economy to ship the ammoniacal liquor in the moderate strength usually required by the chemical companies.

If the market is quite distant, it becomes a question of the cost of transportation in shipping the liquor or advancing it to the ammonia sulphate.

In this case it is evident that the manufacture of ammonia sulphate, at the coke ovens, would be the true economy, as the freight charges on the ammoniacal liquor would be quite large.

It may be noted in this inquiry, that it requires 3,520 gallons of 2° Twaddell of the liquor to make 1 net ton of the sulphate of ammonia, composed as follows:

59.41 %	SO_3 (Sulphuric Acid).
25.06 "	NH_3 (Ammonia).
0.018 "	Fe_2O_3 (Ferric Oxide).
15.512 "	H_2O (Water).
100	

About 8 per cent. of ammonia is lost in the manufacture of ammonia sulphate.

TABULAR STATEMENT EXHIBITING THE ESTIMATED COST OF THE MANUFACTURE OF AMMONIA SULPHATE FROM AMMONIACAL LIQUOR.

NUMBER.	MAKING ONE TON OF AMMONIA SULPHATE.													REMARKS.
	Gas Liquor.	Sulphuric Acid, 1 Ton.	Lime.	Coal.	Labor.	Casks and Packing.	Sundry Repairs.	Wear of Plant.	Interest on Plant.	Strength of Liquor.	Total Amount.	Value per ton.	Profit per ton.	
I.	$12.00	$12.50	$0.90	$1.00	$3.25	$1.25	$1.50	$0.83	$0.50	4° T.	$33.73	$55.00	$21.27	American
II.	12.00	12.50	0.95	1.00	3.50	2.00	1.50	0.70	0.45	4° T.	34.60	55.00	20.40	"
III.	12.00	12.50	0.25	1.25	4.74	0.81	1.12	0.75	0.45	6° T.	33.87	55.00	21.13	"
Average	12.00	12.50	0.70	1.08⅓	3.82⅓	1.35⅓	1.37⅓	0.76	0.46⅔	4⅔° T.	34.06⅔	55.00	20.93⅓	"

In the larger coke works, producing by-products, this inquiry broadens in its general aspect, involving two important considerations; first, whether it is more advantageous to supplement the condensing plant with an ammonia factory and tar boiling plants, or second, to invite some established chemical company to erect, at the coke works, a chemical plant to receive and treat the crude by-products, advancing them to tar and ammonia sulphate, with resultant distillates; thus economizing the freight expenses in handling these products.

There are some difficulties in establishing an equitable basis for regulating the prices of the crude products. This standard might be founded on the market value of the crude materials, or on their finished products, less the freights, in either condition, to the nearest reliable markets.

On the whole, it would appear that a direct reference of the value of these by-products in the crude state, in the tanks at the works, would prove the more practical.

The rates to be paid could be determined by their market values, deducting the freight thereto at such stated intervals as would be equitable to the producer and manufacturer.

An experiment has recently been made to utilize *benzole* in enriching illuminating gas.

So far the results appear to be very encouraging. Should this new application prove successful, it would add materially to the revenue of the coke manufacturer, from the tar by-product.

It has been found that in tar boiling, about two gallons of this distillate can be secured in the making of one ton of coke. The benzole is estimated to be worth 13 cents per gallon.

APPENDIX.

Coke Manufacture in Germany, by Frank H. Mason, Consul General U. S. at Frankfort, Consular Reports.—Manufacture of Coke, Consular Reports, by the late R. de Soldenhoff, Anthony Howells, Consul, Cardiff, Wales.—Mr. Joseph D. Weeks on these Reports.—Tabular Statement exhibiting the work of Bernard Oven.—Statement exhibiting the actual Work and Cost of making Coke and saving the By-products of Tar and Ammonia Sulphate in the the G. Seibel Retort Coke Oven.—Table showing comparative Tests of Bernard and Coppée's Coke Ovens; France, 1889.—Coke Pushing Machine for discharging Coke from retort or narrow Ovens.—Benzole carburetting Apparatus for reënforcing Illuminating Gas, *American Manufacturer.*—Separating and Coal Washing Plant, with Briquette and Eggette Press.—Details of Press and Elevator.—Coal and Coke Loader, *American Manufacturer*—Semet-Solvay Retort Ovens, Report of Tests made in Coking Connellsville Coal, and on Furnace Tests on the Coke Produced.

YIELDS IN BY-PRODUCTS.

In an editorial in *The American Manufacturer* (Jan. 18, 1895), Mr. Jos. D. Weeks, commenting on an answer made by a representative of the Semet-Solvay by-product oven to a statement which appeared in a report of Consul-General Mason (see following pages), of the yield in tar and ammonia in the Semet-Solvay oven, as compared with the Otto-Hoffmann oven, says:

"The statement referred to was intended to demonstrate the superiority of the Otto-Hoffmann coke oven, and was, we believe, first prepared by an American representative of this oven. It also included a comparison with what is termed the Carvès-Hüessner oven.

"As this is probably the beginning of what promises to be an exceedingly important contest, it may not be amiss to say that there are certain preliminary considerations that should always be borne in mind in comparing the results of the operations of different types of ovens.

"One of the first of these, evidently, is that all comparisons of yield of tar and ammonia are utterly valueless unless the coal used is the same, or, if different, unless allowance is made in the comparison for the difference in the amount of by-products contained in the coal.

"The original statement, published by Mr. Mason, was as follows:

System.	Time.	Yield Sulph. Am.	Tar.
Otto-Hoffmann	Oct., '92–Mar., '93.	1.18%	3.53%
Carvès-Hüessner	Oct., '92–Feb., '93.	1.00	1.81
Semet-Solvay	Oct., '92–May, '93.	0.61	1.60

"Nothing is said definitely about the coals used at these ovens except in a general way to state that they are substantially the same, which is evidently a mistake. No Otto-Hoffmann ovens are in operation outside of Germany and Austria, and most of the Semet-Solvay ovens are in Belgium. Now, the Belgian coals used in the Semet-Solvay oven carry from 14 per cent. to 18 per cent. of volatile matter, while the Westphalian coals used in the Otto-Hoffmann ovens carry 20 per cent. to 25 per cent., so that these coals are not the same. There is one plant of Semet-Solvay ovens in Westphalia, that at Ruchrart, but these ovens work on a coal mixture containing 25 per cent. of anthracite, with 75 per cent. Westphalia coal, so that no comparison can be made between the Otto-Hoffmann and this bank of Semet-Solvay ovens as to yield of tar and ammonia. Mr. Darby's figures are equally misleading, as he is working a coal with 33 per cent. to 35 per cent. of volatile matter. It is evident, therefore, that without further details, the comparison in the table between the Otto-Hoffmann and Semet-Solvay ovens is valueless.

"A similar statement is true, though to a less extent, of the comparison between the Hüessner and Otto-Hoffmann ovens. Unless the report of yield of the Otto-Hoffmann ovens is for Germania II. plant, the coals used are not the same; or at least Dr. C. Otto & Co., who own the Otto-Hoffmann ovens, state in a communication in *Stahl und Eisen*, December, 1892, in effect that they do not use the same coal as Hüessner, except at Germania II. plant.

"Again, the length of time the ovens have been in operation must be considered. We imagine that the Otto-Hoffmann yields are those of the most recent plants, while the Hüessner ovens were built in 1882, and are twisted and cracked, as the result of the sinking of the ground from working out the coal underneath.

"There are other facts, also, that should be known before a comparison can have any value. It is well known that coking is a process of distillation, and that in distillation the character and amount of the volatile products, or on the other hand, of the solid residue, can be changed at will within certain limits. As a rule, the hotter the oven or retort, the less the yield of tar and ammonia, and the greater the yield of gas and the better the coke. There is no doubt but that the yield of tar and ammonia in the Otto-Hoffmann oven is larger, as a rule, than in any other oven. Whether it is larger when all things are considered, is not yet acknowledged by the other oven owners, at any rate it will be wise for those contemplating the erection of ovens to examine this question very carefully."

COKE MANUFACTURE IN GERMANY.

(U. S. Consular Reports.)

INTRODUCTORY REMARKS.

Coke is the fixed carbon and inorganic ash of bituminous coal, from which the volatile elements have been expelled by roasting in a close chamber, with or without exclusion of air. Coke of the highest quality is firm and columnar in structure, porous in texture, with a metallic resonance and bright, silver-gray color, and the theoretic coking process is that which will most cheaply secure the largest percentage of this product by not only conserving in the coke all the fixed carbon of the coal, but securing the deposit of part of the free carbon which is expelled in the form of hydro-carbonic gases during the process of dry distillation.

The progress of the past thirty years in the metallurgy of iron has established coke as the all but universal fuel for smelting ores in blast furnaces. The same period has witnessed the advance of the United States to the first position among the nations as a producer of pig-iron, the output of our country in 1892 being 9,157,000 tons against 6,616,000 tons for Great Britain, 4,793,000 tons in Germany, and 5,413,000 in all other countries. In view of this and the recognized preëminence of Americans in all that relates to the clever organization of industries and prompt adoption of improved methods, it would seem incredible, if it were not a fact patent and undeniable, that the United States are at least ten years behind western Europe in the scientific economy of coke manufacture.

Two causes are generally held responsible for this curious and costly conservatism—an abundance of cheap and excellent coking coals, and a timid, complacent fogyism on the part of certain leading iron-masters, partly the result of deference to English traditions, and partly due to superficial and too hastily abandoned experiments with the retort ovens which Belgium, France, and Germany have since developed to such admirable perfection. Ten or twelve years ago some trials were made with a primitive form of retort oven which consumed the gases evolved by coking, but whether from defects in the apparatus or want of skill in its management the results were disappointing, and the idea became fixed that retort oven coke was inferior for smelting purposes to that produced in the old-fashioned "Bee-Hive" oven, which still pours out, in clouds of wasted wealth, the smoke and gases that blacken and defile the coke districts of West Virgina and Pennsylvania. England was for a long time equally conservative, and as late as 1882 Dr. Augus Smith wrote in his official report: "The present method of making coke in England has all the appearance of roughness and savagery, which wanton extravagance always produces."

Meanwhile Belgium, France, and Germany, with coking coals generally dearer and far inferior to those of Durham and Connellsville, were forced by the stern necessities of competition toward more frugal and progressive

methods, and during the past twelve years they have developed the retort-oven processes to a degree of economic perfection which has revolutionized the whole theory and practice of coke making, and given to the iron and steel industries of these old countries an inestimable support against the steadily declining prices of the metal market. However well founded may have been the objections of furnacemen to retort oven coke a dozen years ago, those defects no longer exist; the coke made to-day in such ovens from Westphalian and Silesian coals is not only superior in yield but fully equal in quality to the best ever produced from the same materials by any other method, whether judged by the records of fuel practice in German furnaces or by the excellence of their products in iron and steel.

During 1892 there were produced in Germany, 6,843,330 tons of coke, exclusive of that derived from gas manufacture. Of this large output 4,360,984 tons, or 67 per cent., were manufactured in the Ruhr district of Westphalia, where the best coking coals of Germany are mined, and where are concentrated in a few square miles of territory, with Essen as its center, the most important iron and steel industries of the Empire. Of the total coke product of Westphalia during the year cited 3,064,817 tons, or 78 per cent., were consumed in blast furnaces. Its price in the market of that year averaged $2.61 per gross ton, equal to about $2.40 per net ton of 2,000 pounds. From the American standpoint this may seem a costly fuel, but it must be remembered that the best Westphalian coking coals lie from 500 to 1,200 feet below the surface, are limited in quantity, and when mined are so mixed with slate, pyrites, and other impurities that before coking they must be crushed and washed, whereby they lose from 12 to 20 per cent. of their crude weight, and contain, when dumped into the coking oven, from 10 to 18 per cent. of water. The question at once suggests itself: How can the German iron-masters, importing their ores largely from Spain, Morocco, and Scandinavia, hold their own in the prostrate metal markets of to-day? That they really do this is evident, not only from the current statistics of their industry, but from the steady, prosperous activity which prevails in Westphalia, where one may traverse the entire valley of the Ruhr and see scarcely a silent mill or an idle chimney. Not infrequently blast furnaces in the Ruhr district are not only flanked by a long row of coke ovens, but have also a coal mine on the same premises or in the immediate neighborhood, so that the item of fuel transportation is reduced to a minimum. This brings us to the question of what the Germans save, as compared with their American rivals, by their superior skill and economy in coke making.

On the first of the present month there were in operation in Westphalia alone 9,780 coking ovens, of which 6,599 belong to members of the coke syndicate; 387 are worked independently by mine owners outside of the syndicate, and 2,794 are owned and run in connection with iron-works. Of this whole number, 980 ovens have condensation plants for the recovery of

by-products, 8,688 are of the Otto-Coppée type, without condensing apparatus, and 112 are old-fashioned "Bee-Hive" ovens, the product of which is largely exported to Japan and Australia. There are also at Krupp's works, in Essen, a few Bee-Hive ovens about twenty-five years old, but whether they are still in service could not be ascertained. Practically, therefore, the steel and iron of the Ruhr district are made with coke produced in retort ovens, which are of four different models, viz, the Carvès-Hüessner, the Semet-Solvay, and the Otto-Hoffmann, with condensing apparatus, and the Otto-Coppée without condensing plant. All these ovens are similar in general theory, though differing in certain details of construction, and all of them are superior to the most perfect Bee-Hive oven in respect to five fundamental points, viz: (1) Larger yield of coke from the same coal; (2) reduction of time required for coking; (3) reduced cost of attendance and labor, the ovens being discharged by machinery; (4) less costs of repairs and longer life of ovens; (5) saving of gas and the secondary products.

There are in the Westphalian coal basin 130 known veins of coal, 76 of which are workable. Of the workable veins, 18 yield coking coals of various grades, containing anywhere from 18 to 28 per cent. of volatile matter, but none of these, not even the best, as will be shown later in this report, are equal to the average Connellsville or Pocahontas deposits, which furnish the standard coking coals of the United States. For the Ruhr coals, which are so low in volatile elements as not to justify the erection of condensing plants for the recovery of by-products, the form of retort-oven known as the Otto-Coppée model is generally used, and it is noticeable that whenever in Westphalia a blast furnace company makes its own coke, only retort ovens are employed, and to this rule there is not a single exception.

There are now in operation in the Ruhr district 9,602 retort coking ovens, of which 978 have condensing plants for the recovery of by-products. The number of each type in the latter category is: Otto-Hoffmann, 776; Carvès-Hüessner, 100; Semet-Solvay, 48; System Herbetz, 48; System Brunck, 6; total, 978.

The Brunck ovens have not been successful, and as those of the Herbetz system belong to an old Coppée plant, to which a primitive condensing apparatus has been attached, they do not require separate consideration. The three systems first named are the only real competitors in the race, and they are hereinafter briefly described. In respect to general form, outward appearance, method of filling and discharging, as well as in the uniform excellence of the coke produced by all, they are quite similar; but they differ in size, method of heating, and especially in construction of the heating-flues in their side-walls, which in the Hüessner and Solvay oven are horizontal, while in the Otto ovens they are vertical. The Otto ovens are the largest, the Hüessner somewhat smaller, and the Solvay smallest of the three. In respect to heating, the two latter employ the recuperative principle for pre-heating the air for combustion with the cleansed gases of distil-

lation, while the Otto-Hoffman oven employs a Siemens regenerator for the same purpose, and heats the air to a much higher temperature.

1. THE CARVÈS-HÜESSNER SYSTEM.

The Carvès oven was invented in France, and was first used a number of years ago in the district of St. Etienne. There it was seen and studied by Mr. A. Hüessner, a German engineer, who obtained from the inventor rights and drawings, and introduced the oven into Germany with several improvements of his own, which, according to the record, were patented in this country under numbers 16,921 and 20,196. Mr. Hüessner constructed, at his own expense, in 1881, at Bulmke, near Gelsenkirchen, 50 ovens, to which was added a second group of 50 more in 1884, and these have since been operated as a single plant with condensing apparatus for the recovery of tar and ammonia, and are the only ovens of that type that have yet been erected in Germany. Their size, as given in Lunge's treatise on coal distillation, is: Length (inside mesurement), 29 feet 6 inches; mean width, 22½ inches; height, 5 feet 11 inches. Like all ovens of this class, they taper slightly in width from one end to the other to secure facility in discharging, which is effected by a steam ram, or pusher, armed with a shoe of nearly the same size and shape as a section of the oven, and which, when the coking operation is finished and the end doors opened, shoves the entire charge of glowing coke out upon a sloping platform of iron tiles, where it is sprayed with water to arrest combustion on exposure to the air. An oven is in this way emptied of its entire charge, 4 or 5 tons of coke, in less than half a minute, and refilled in twelve to fifteen minutes more.

Beneath the oven, and extending its entire length, is the combustion chamber, in which the gas is burned with air that has been heated to about 500° F., by passing through a lower flue warmed by off-heat from the spent flame which has made the circuit of the oven flues. The gas is introduced into the firing chamber by an annular double tube, like a Bunsen burner, the inner tube of which conveys the air, which is thus mingled with the gas at the moment of ignition. Here it bursts into flame, producing an intense heat, which rises through a perpendicular flue to the top of the oven and descends through the long alternating flues which are made of large tiles, built into the side-walls which form partitions between adjoining ovens. The end walls between each pair of ovens are strengthened by buttresses of masonry, which at the same time cover the ends of the horizontal flues. The ovens are charged from above with from 5.5 to 6 net tons of finely crushed coal. The charge is regulated to fill about 88 per cent. of the interior space, while the remainder is left vacant for the free circulation of the gases evolved by roasting.

The oven thus filled, it is heated by the hearth and side-flues, and being already glowing from the previous charge, the coking process begins at once

at the sides and bottom of the mass, gradually extending inward and upward until the volatile elements of the coal are throughly expelled. The gases are drawn off by the suction of an exhauster into large pipes which convey them to the condensing plant, where, after passing through a receiver, coolers, and scrubbers, and being thoroughly cleansed of tar and ammonia, they are returned to the ovens to be injected and burned with pre-heated air, as already described. The time required varies with the nature of the coal, from forty to forty-eight hours, and a ton of the high quality of coal which is coked at Bulmke produces about 8,500 cubic feet of gas. A special contrivance of Director Hüessner is a system of small pipes connecting the main gas pipe with the ends of the upper horizontal flues, by which, when necessary, a small jet of live gas can be turned in to increase the heat at the outer or exposed end of an oven when it becomes too cool. The progress of the process is watched through a small peephole in the oven, and when the gases cease to evolve, the connections are shut off, the doors swung open, and the oven discharged as already described.

The cost of the plant at Bulmke was, according to Lunge, who copied his figures from an official report of the company, $204,445 for the 100 ovens and condensing plant, buildings, etc., or $2,044 per oven. Director Hüessner now gives the following estimates for the construction of a similar plant, viz. Ovens, $833 each; condensing apparatus, $452 per oven; ammonia works, $119 per oven; and piping, valves, etc., $261 per oven; total, $1,666 per oven, or $166,000 for an outfit of 100, not including cost of land, railroad connections, etc. The works at Bulmke are not connected with any coal mine or furnace, but are operated by a stock company under the management of Mr. Hüessner, who buys and uses the best Westphalian coking coals and sells his product to the neighboring iron and steel makers. The average yield is given by Mr. Hüessner as follows: Blast furnace coke, 72 per cent.; crushed and small coke, 5 per cent.; tar, 2.10 to 2.77 per cent.; sulphate ammonia, 1.10 to 1.13 per cent. These results are somewhat higher than those stated by Mr. Austin Farrell, an American furnace engineer, who made last year a careful study of the plant at Bulmke and its records, and states in his unpublished report, that during the period from October, 1892, until February, 1893, inclusive, the yield of the Hüessner ovens working on coal containing 29 per cent. of volatile matter was: Furnace and crushed coke, 70 per cent.; braise, 7 per cent.; tar, 1.81 per cent.; ammonia, 1 per cent.

This apparent discrepancy Director Hüessner explains by the statement that during several years he was greatly troubled by the irregular sinking and settling of the ground under his works the result of underground mining operations, so that the walls cracked and joints and seams were opened in the oven flues, permitting the escape of oven gases into the flues, where they were consumed and lost, thereby reducing the percentage of recovered by-products. During the past eight months these sinkings of the ground

have measureably ceased, with the result that his practice has improved and surpassed the previous record in tar and ammonia, thus reaching the percentages which are above given. Evidences of the sinking ground are to be seen all about the place; huge cracks appear in the foundation wall, and one entire wall of the ammonia building has fallen out and has been replaced by a wooden partition.

The labor required in operation employs in all 67 men in two ten-hour shifts—57 men at the ovens, 5 at the gas-cooling plant, and 5 in the ammonia building, and the net cost of labor is stated to be 1.50 marks or 33.8 cents per ton. The coke made by the Hüessner ovens at Bulmke is of excellent quality, firm, porous, resonant, and of a standard color except where it is outwardly blackened, as all retort coke invariably is, by being sprayed with water on coming from the oven.

2. THE SEMET-SOLVAY SYSTEM.

The Semet-Solvay coking oven is of Belgian origin, the first six of that type having been erected at Mons in 1882, and it is the standard model used in that country in combination with condensing apparatus for the recovery of by-products. The central office of the Solvay Company is at Brussels, and it has built and put in operation 492 ovens since 1885. Of these 327 are located in Belgium, 50 in France, 55 in England, 12 at Syracuse, New York, (Solvay Soda Process Company), and 48 ovens at the Phoenix Steel Works in Laar, near Ruhrort, Germany, which last have been in operation since April, 1891.

The dimensions of the Semet-Solvay ovens at Laar are: Length, 30 feet; height, 5 feet 10 inches; mean width, 17 inches. They are thus considerably narrower than either the Hüessner or Otto ovens, and take in fact only from 4 to 4.5 tons of coal at a charge, but they work at a very high temperature, and the operation is usually completed within twenty-four hours. The records show that the 24 ovens at Laar coke 3,285 tons of coal per month, and 39,420 tons during an uninterrupted year's run.

The distinctive feature of the Solvay ovens is the construction of the heating flues and the side-walls which separate the ovens. Like those of the Hüessner type, the heating flues are three in number and horizontal, extending the entire length of the oven, and so provided with openings from one to the other that the descending current of burning gas traverses the entire length of all the flues, a distance of about 90 feet. But unlike all the others, the Solvay flues are made of consecutive joints of large, hollow tiles, closely matched and set in heavy fire-brick walls, 16 to 20 inches thick, in such manner that only one side of the tile is exposed and forms part of the heating surface of the oven, the top, bottom, and back of the tile being covered by the masonry. The side of the tile through which the heat passes is 2.8 inches thick, and the construction of the buttresses between the ovens gives the whole plant great solidity, resists the side pressure exerted by the swell-

ing coal and by the ram in discharging, and enables the ovens to be worked at a high temperature and rapid pace. The operations of charging and discharging are precisely similar to those employed with the Hüessner and Otto ovens. They are kept in constant service day and night throughout the year, and when working with quick coal are said to average slightly more than one charge per oven each twenty four hours.

The gases of distillation are drawn off to the condensation plant, where they are cooled, washed, and deprived of their tar and ammonia, and are then conducted back to the ovens, where they are introduced by pipes and tuyeres from the main conduit into the ends of the upper and middle horizontal flues respectively. This supply of gas at both ends of the oven secures an equal distribution of heat throughout its length. At each point of injection the in-rushing gas meets and is mixed with a supply of air coming up through a feed-pipe from a heating chamber beneath the hearth of the oven, where it has been warmed in passing to a temperature of 360° F. to 500° F. Thence the flame passes downward, traversing successively the alternating horizontal flues, and emerging into a large canal or reservoir at the bottom, whence the heat is drawn off and used for heating boilers or other purposes. The pressure of gas in the tuyeres is regulated by an ingenious automatic govenor, which thus equalizes the supply, so that the heat in the flues is kept uniform and constant. The generators in which the air is warmed have a heating surface of from 6 to 10 square meters for each oven, and the saving of surplus gas from coal containing 17 per cent. of volatile matter, is about 25 per cent. of the whole amount generated by the coking process. This surplus gas is stable, and can be used either as fuel or for illuminating purposes.

The cost of constructing Solvay ovens in Belgium, where both labor and materials are cheaper than in Germany, is about $1,160 for each oven with all necessary fixtures, and $675 per oven for the condensing plant—in round figures $2,000 per oven for the entire outfit for coking and saving tar, ammonia and fuel gas. The labor is substantially the same during the operation as that required by the retort ovens of other types. For the best results the Solvay ovens require a uniform and carefully sustained quality of coal, and for this reason there is provided at Laar an apparatus for mixing two or more kinds of lean and fat coals in such manner that the resulting mixture shall contain from 20 to 25 per cent. of volatile matter. This mixing process in addition to transportation from the mines where it is crushed and washed, reduces the free water in the coal used there to 7 or 8 per cent., while much of the coal coked by other ovens in connection with Westphalian mines, contains from 15 to 20 per cent. of water.

In respect to rapidity of working and good quality of coke produced, the Semet-Solvay ovens have a well established reputation, but owing to the very high temperature at which they are worked, and the rapidity of their action, their saving of by-products falls below that of the other types which are described in this report. The report of Mr. Farrell, the American furnace

engineer already alluded to, who spent three months in Europe last year investigating the different coking systems, and who had access to the records of all leading oven builders, gives the following comparison of results in by-products, as accomplished by ovens of the different models working on similar grades of Westphalian coal.

Names.	Period.	Tar.	Sulphate of ammonia.
		Per cent.	Per cent.
Semet-Solvay	October, 1892 to March, 1893.	1.6	0.61
Carvès-Hüessner	October, 1892 to Feb., 1893.	1.81	1
Otto-Hoffman	October, 1892 to March, 1893.	3.53	1.18

In Belgium the Solvay ovens work successfully on coals as low as 15 and 17 per cent. in volatile matter, and the two plants at Brymbo and Northwick in England have achieved satisfactory results.

3. THE OTTO-HOFFMAN SYSTEM.

By far the most important and widely distributed kind of retort-coke ovens in Germany is that of Dr. C. Otto & Company, whose central office is at Dahlhausen, on the Ruhr. This company builds retort ovens of two types, (1) the Otto-Coppée model, which saves as fuel the gases of distillation and is used on account of meager volatile elements in the coal, or for other reasons the recovery of by-products is not attempted; (2) the Otto-Hoffman oven, with condensing apparatus, which by common consent constitutes the most advanced and perfect equipment of its kind now in use in this country.

The first ovens of the Otto-Hoffman model were built in 1881, and there are now at work in Germany and Austria 1,855 ovens of that type, to which various improvements have been successfully added, and 6,309 ovens of the Otto-Coppée class without condensing apparatus, in all 8,164 retort ovens—far more in number than have been built by all other constructors in all countries combined. Of the 978 retort ovens of all models with condensing plants now at work in Westphalia, 776 are of the Otto-Hoffman type; the remaining 202 include the 100 Hüessner ovens at Bulmke, and the 48 Solvay ovens at Laar, above described. The remaining Otto ovens of both classes, which complete the grand total, are distributed through the Saarbrück region, Upper and Lower Silesia, and the neighboring coal district of Austria.

The standard Otto-Hoffman oven for Westphalian coal is 32 feet and 8 inches long, 5 feet 7 inches high, 21.5 inches wide at the narrow, and 25 inches at the other end to facilitate discharging it. It is therefore the largest of the three models, and takes at a charge from 6.5 to 7 net tons of coal, which is delivered, perfectly coked, in from thirty-two to forty-eight

hours, according to the nature of the coal. The ovens are built for convenience and economy of management in batteries of 60, divided into 2 sections of 30 ovens each. These sections are separated by an open-roofed space, where the various pipes and conduits which connect the ovens with each other and with the condensing plant are brought together under the control of the valve-tender. The ovens are heated by a portion of the gas evolved by the coking process after it has been purified of tar and ammonia, and the process is concisely as follows: The oven being filled and the heat turned on, distillation begins at once, and the gases, mingled with vapor and some coal dust, rise and are drawn by an aspirator through large pipes to the reservoir, where they are cooled and deprived of the heavier portion of the tar. Thence the gas goes to the receiver, and so on through the condensers, where it is cooled and washed clean of tar and ammonia, and is then returned through a main pipe which has feed-cocks leading into the hearth-flues, one of which underlies each oven. This is the combustion chamber, where the gas on entering meets about ten times its volume of air, which has been pre-heated in a Siemens regenerator to about 1,800° F., and immediately develops a heat of from 2,300° F. to 2,800° F. The flame then passes along the combustion chamber up through the vertical side-flues in one-half of the oven, thence along the top and down the vertical flues on the other side into the second regenerator, where it gives up most of its remaining heat, passing afterwards under a couple of steam boilers, and finally out through valved openings into the chimney with a temperature reduced to 500° F., or 600° F. There are two regenerators—long chambers of masonry filled with fire-brick, lattice, or checkerwork—which take up and save the heat of the spent flame and afterwards return it to the air for combustion with the gas. These regenerators are in the brick foundation, and extend along the entire length of the ovens on either side, and the arrangement is such that when one regenerator has become cooled by the inrushing current of air to about 1,300° F., the other has been raised by the off-heat of the spent gas flame to 1,800° F., or 2,000° F. A valve in the main feed-pipe is then turned, which reverses the currents of gas and air through the entire apparatus, so that the off-heat is turned into the cooled regenerator and the air comes through the hottest one to the firing chambers. By thus reversing the currents at intervals of an hour, the off-heat is utilized to the utmost degree, an intense and perfectly governable heat is generated and maintained in the coking ovens, and from 30 to 40 per cent. of the gas generated in coking is saved as surplus for heating or illumination. It has been demonstrated that a battery of 60 Otto ovens, coking 102,500 net tons of coal per year, will save an amount of gas equal in fuel value to 11,750 net tons of coal.

In ovens of the Otto-Coppée type the gases of distillation are drawn by chimney draft directly from the top of the coking chamber into the vertical side-flues, where they meet the air necessary for their combustion. The products of combustion then descend the side-flues, into the hearth or

base flue, and thence pass into a large collection canal which carries them to the boilers, where the remaining heat is sufficient to evaporate from 1.1 to 1.7 pounds of water for each pound of coal coked.

Another feature of the Otto-Hoffmann system is that by proper regulation a slight pressure is maintained in the heating flues instead of a partial vacuum, as occurs in the long horizontal flues of the Hüessner and Solvay ovens. As a result of this, any incidental crack or fault in the side-walls of the Otto oven would not entail an escape of retort gas into the flues (as happens in case of such accident to either of the other types), and this has an important effect on the comparative savings of by-products, since the retort gas which escapes by leakage into the flues is burned and lost. The labor for a battery of 60 Otto ovens with a by-product saving plant requires two daily shifts of 47 men each, viz., 29 men and 2 foremen at the ovens, and 14 men with 2 superintendents in the condensing department. The total pay roll for labor and superintendence amounts to 28.8 cents per ton of coke produced. At the Bee-Hive ovens in America, where no by-products are saved, the cost of labor for coking alone varies from 32 to 35 cents per ton.

The average yield of the two Otto-Hoffmann plants of 60 ovens each in Westphalia, the records of which for 1893 have been personally examined for the preparation of this report, was as follows:

Description.	Julia mine.	Recklinghausen II.
Number of ovens drawn	880	849
Charge per oven, dry	6.45 net tons.	6.78 net tons.
Average coking time	49.78 hours.	49.94 hours.
Percentage of coke	78	74.47
Percentage of tar	3	3.70
Percentage of sulphate ammonia	1.15	1.28

The cost of construction in Germany for Otto ovens is $1,168 each, and $1,636 per oven for the condensing plant; and it is to be remarked that throughout the latter everything, from the engine to the smallest pipe or pump, is in duplicate, so adjusted that in case of accident or failure of any kind the duplicate fixture can be turned into service and the work continued without a moment's delay. This practice of duplicating the entire condensation apparatus adds largely, of course, to the cost of the outfit, but it not only provides against accident but enables everything to be kept clean and in perfect order, and long experience has taught the Otto company that such extra cost is amply justified and repaid. Nothing is more striking than the quiet and cleanliness which prevail about these establishments. Nothing is wasted; scarcely a fleck of smoke escapes from the ovens or rises from the tall chimney. The air is clear and undefiled with soot, and luxuriant crops of grain and vegetables grow up to the very walls of furnaces and coking plants in this country, where every morsel of food is needed, and where waste is considered a crime.

HEATING FLUES.

Aside from the different methods of heating employed by the three foregoing types of ovens, the point most disputed in their construction is that of the heating flues, through which the burning gas is passed to heat the coking chambers. In the Hüessner and Solvay ovens, as has been seen, these flues are horizontal, and are made of large tiles set in the side-walls which form partitions between the ovens. In the Otto ovens these flues are vertical, and are built of fire-brick of ordinary size. Each constructor claims that his plan is the best, but the weight of testimony seems to show that the verticle flues are cheaper to construct, stronger in resisting side-pressure from the coal or ram, and more easily repaired when worn or accidentally injured. From all accounts, the Otto ovens have shown great durability under constant service at high temperatures abruptly checked by successive charges of wet coal. There are numerous plants of this model in Westphalia, which have been working constantly for twelve years or more with only nominal repairs, and are still in good condition. At the Germania II mine, near Dortmund, where 60 Otto-Hoffmann ovens have been at work for more than eight years, there occurred last year a miners' strike which cut off temporarily the supply of coal, so that it became necessary to shut down 30 of the ovens, and advantage was taken of the chance thus offered to look over and repair them. This, after an unbroken run of eight years, was done at a cost of $470 for labor and materials—an average of $15.90 per oven, or less than $2 per oven per year. The one fact that makes this instance noteworthy is that this plant stood on ground that had settled 5½ feet during the eight years, by reason of mining underneath; but notwithstanding this, the conditions of the ovens had remained so intact that the yield of both by-products had steadily increased.

It is unfortunate for the purposes of this comparison that the Hüessner and Semet-Solvay coking ovens are each represented in Germany by only a single plant, which, whatever their individual merits, play but a minor role in the presence of the numerous and admirably appointed establishments of the Otto Company. The overwhelming preponderance of the Otto ovens in this country is due to two causes—first, the settled conviction of a large majority of German coal and iron men that they are the most effective and durable ovens ever devised for working German coals, and secondly, to the consummate skill and enterprise with which the business of the Otto company has been managed. Dr. Otto began his career in this field almost without financial resources, and in face of the then prevailing prejudice against retort oven coke. Not finding a furnace-master or mine-owner willing to risk the cost of an experimental plant, he secured the requisite capital and built at his own expense, in 1881, 10 ovens at the Holland mine, and 40 more at the Pluto mine in 1883. These were built by an agreement with the mine-owners that they should furnish the coal and receive in return all the coke, Dr. Otto retaining for his outlay and labor

simply the tar and ammonia which he might recover from the gases of distillation. This plan proved so profitable for all parties concerned that it has been substantially continued to this day, and the finely equipped coking and condensing plants of the present Otto company are still built in Germany under contracts in effect as follows: The company having ascertained by analysis that the coal of a certain mine is sufficient in quantity and rich enough in tar and ammonia to justify the venture, contracts are made to erect at its own cost and run for a term of years a specified number of ovens with condensing equipment, the mine-owner to supply the coal and the small amount of steam required by the engine of the by-product apparatus and pay for the labor of the coke ovens. In return the mine-owner receives all the coke and the off-heat which remains as surplus from the regenerators; the Otto company pays all initial cost of construction, as well as superintendence and labor in the condensing department, repairs, etc., and receives as its share the tar and ammonia that are recovered. At the end of twelve years the whole establishment is by contract turned over as a free gift to the mine-owner. The vital fact that proves more than volumes of discussion, is that this plan, which was begun twelve years ago is still continued, and the company is erecting this year nearly 300 new ovens, involving, with all appurtenances, an outlay of more than $800,000. It is understood that in more than one instance the by-products recovered by the Otto system have paid for the entire coking and condensing plant within three years, leaving to the constructing company a nine years free run for net profit.

GERMAN RETORT OVENS FOR THE UNITED STATES.

A year ago this question might have involved some reasonable doubt, but such uncertainty has now been dispelled by actual demonstration. During the summer of 1893, 18 tons of Connellsville coal were brought to Germany and coked, in the presence of an experienced American furnace manager, by the Otto-Hoffmann ovens at Recklinghausen in Westphalia. The results, which have been published in many technical journals in the United States, exceeded all expectations, and may be briefly summarized. The coal was mined at the Valley mine, near Scottdale, Pa., shipped to Germany, and showed under crucible test: Moisture, 1.59 per cent.; volatile matter, 29.18 per cent.; fixed carbon 58.84 per cent.; ash, 9.40 per cent.; sulphur, 0.99 per cent. The theoretic yield of coke from such coal would be 68.74 per cent. After preliminary tests with small quantities, two ovens were charged with 7 net tons each of the coal, and finished the process of coking in twenty-eight and thirty-two hours respectively. The yield was: Blast-furnace coke, 71.19 per cent.; small coke and braise, 2.5 per cent.; total coke, 73.6 per cent. The report of the American expert declared it to be of "most excellent quality, very hard, with metallic ring and silvery luster—impossible to distinguish from the original Connellsville Bee-Hive coke made from the same seam of coal."

A sample of this coke was exhibited at the Westphalian Mining Exposition at Gelsenkirchen and attracted general admiration, being pronounced by the German furnacemen distinctly superior to the best coke made here from native coals. Another sample was sent to the United States and the remainder of the lot left to the mine-owner at Recklinghausen, who discreetly concealed it by mixing through a number of car-loads so as not to demoralize his customers by a noticeable improvement in quality, which he could not afterwards maintain. Standard authorities give the charge of an ordinary Bee-Hive oven in the Connellsville district at 3.8 tons, the time required for coking at 48 hours, and the average yield 58 to 60 per cent. of furnace coke. Comparing these figures with the experiment at Recklinghausen, it will be seen that with the same Connellsville coal an Otto-Hoffmann oven effects a saving of sixteen hours in time, yields from 11 to 12 per cent. more coke from every hundred units of coal, and saves a large percentage in the cost of labor, to say nothing of the recovery of secondary products, which the Bee-Hive oven wastes altogether.

How promising a field Pennsylvania and West Virginia may open for the best class of retort ovens will appear from the following comparison, in which are included the results of a second test of 30 tons of other American coal in April of this year at the same ovens in Recklinghausen :

COAL.	Coke and Braise.	Tar.	Ammonia.	Gas Per Ton.
	Per Cent.	Per Cent.	Per Cent.	Cubic Feet.
Connellsville	73.6	4	1.07	9,821
Pocahontas	84 8	1.7	0.716	9,131
Westphalian	76	3	1.15	8,744
Silesian	67	4.2	1.12	10,037

But not all American coals are of such high quality for coking purposes as the Connellsville and Pocahontas. What will be needed is a retort-oven system that will make furnace coke of the coals of Ohio, Alabama, and Illinois. Nothing is certain in industrial science until it has been actually accomplished, but a coking system which has been worked successfully for years on the varied and often inferior coals of the Laar, Silesia, and Austria, where the proportion of volatile matter varies from 17 to 42 per cent., may be trusted to achieve at least equal success in the United States.

It remains to be said that German iron-masters prefer retort-oven coke to that made by any other method, and years of experience have proven that such ovens, working side by side on the same coals, with and without condensing apparatus, make precisely the same quality of coke. Saving the by-products does not effect in the slightest degree the quality of the coke.

That German coke is good, notwithstanding the large proportion of inferior coal that is coked in this country, will be shown by the following notes of blast-furnace practice at some-well known works in Westphalia and Silesia:

WORKS.	Product.	Ore Mixture.	Coke Consumed.	Iron Produced.
		Per Cent.	Pounds.	Pounds.
Hoerde Iron Works	Thomas Pig	44	2,000	2,260
Heinrich's Furnace	Puddle Iron	43	2,000	2,000
Schalker Furnace Company	Bessemer Iron	47	1,980	2,000
Phœnix Company, Laar	Do	52	1,900	2,000
Sophie Furnace, Silesia	Mill and Foundry Iron.	50	1,980	2,000

MARKET FOR BY-PRODUCTS IN THE UNITED STATES.

As to the future American market for the secondary products of coke manufacture, there would seem to be no reasonable question. Coke-oven tar is superior for nearly all purposes to gas tar, and it is well known that the demand for coal tar in the United States far exceeds the present supply. Its average price in Germany during the past three years has been $8 per ton, while it was $12 per ton in the United States in 1892, during which year there was imported 117,056 tons against 89,313 tons imported during the preceding year.

Ammonia may be derived from coal by the retort-coking process in several marketable forms, such as chlorides, nitrates, carbonate or concentrated aqua ammonia (15 per cent.), all of which have high values. but as the demand for them is limited, the principal product is sulphate of ammonia, for which there is a large and growing demand as a fertilizer of great value for worn soils. For this purpose it replaces Chile saltpeter, which our country imports to the amount of from $2,000,000 to $3,000,000 per annum. The average price of sulphate of ammonia in the American market in 1893 was $63.20 per ton, and the imports of the three preceding years aggregated 15,000 tons, all of which and far more will be saved when the ammonia of the wasted gases of American coke manufacture is recovered by more economical methods. But the greatest gain will be to the iron and steel industries, which, under the present conditions of competition, can no longer afford to ignore the scientific economies of coke production, which other nations have perfected and found so practicable and lucrative.

FRANK H. MASON,
Consul-General.

FRANKFORT, *July 28, 1884.*

MANUFACTURE OF COKE.*

A recent letter of inquiry from a Pittsburg firm, respecting the manufacture of coke, leads me to the conclusion that the following paper, prepared by the late Mr. R. de Soldenhoff, of Cardiff, for the Brussels Congress of the Iron and Steel Institute, will be valuable to all concerned in this important industry. Mr. de Soldenhoff, I may mention, was justly esteemed the highest authority in these parts in that line, and the unique experience which made him an expert in his profession shows itself in what is considered an invaluable contribution to the literature of that industry.

ANTHONY HOWELLS,
Consul.

CARDIFF, *September 26, 1894.*

THE MANUFACTURE OF COKE.

[BY THE LATE R. DE SOLDENHOFF.]

As a source of heat, generated artificially, metallurgy originally made use of wood in its raw state, containing 40 per cent. of carbon and 60 per cent. of moisture and gases. The next step was to transform this wood by artificial means into charcoal, a process well known to all. This fuel practically is the pure concentrated carbon of the wood, with a very small addition of moisture, and a very small proportion of ash, not exceeding 3 per cent. The next step was the utilization of the naturally accumulated carbon, which goes by the name of coal.

This practice is not yet abandoned, as there is in Scotland 1,000,000 tons of pig iron yearly made by using raw coal in the furnaces. There were also some furnaces in South Wales until quite recently. There are, too, some furnaces in the United States, in the northeast of Pennsylvania, using raw coal. Knowing, however, that Great Britain produces pig iron to the extent of about 7,000,000 tons, it is quite evident that the bulk of this production must be made by the help of different fuel than the coal, and it is universally known that it is made by means of coke; and why is it so?

It was found that the coal in its raw state, when hard, free burning, and in lumps, was best suited for blast-furnace working, but the small coal or duff could not be used for the same purpose. The best coals for that purpose in Great Britain are the Scotch coals, and some of the Pembrokeshire anthracitic coals.

The binding or bituminous coals, as a rule, are not used for that object in their raw state. The use of coals in their raw state for blast-furnace purposes has been accompanied by a great amount of waste in the past, on account of the volatile matters in the coal having been totally lost. The magnitude of the waste may be estimated by the fact that in Scotland about 2,000,000 tons of coal yearly are used for making pig iron, which represents an annual loss of 17,000 tons of sulphate of ammonia, worth at least £178,500 a year.

* See "Coke Manufacture in Germany," Consular Reports No. 169 (October, 1894), p. 264.

The Scotch ironmasters, seeing the success of the gas works extracting ammonia in the production of illuminating gas, were led to consider the feasibility of applying a similar processs of extracting the ammonia from the furnace gases.

The difficulties in extracting it, however, are enormous, when it is considered that the whole of the fixed carbon introduced into the furnace, with very small exception, is transformed into carbonic acid and carbonic oxide. In addition to this, there are the carbonic acid of the flux and the nitrogen of the blast, so that the ammoniacal gas does not exceed one-eight hundredth part of the total. Thus, one volume of ammonia is accompanied by 769 volumes of other gases.

It is estimated that each ton of coal burned in the furnace causes a generation of about 90,000 cubic feet of gas, and that it yields only 4.38 pounds of ammoniacal gas. Two eminent firms in Scotland—Messrs. Baird & Co., at Gartsherrie, and Messrs. Merry & Cuninghame, at their Carnboe Works—have erected huge and costly plants to attain the object. It is said that, besides the ammonia, some tar is collected to the extent of 25 gallons per ton. It is, however, found not suitable for extracting aniline colors and benzole, unless it is specially treated. Those that wish to have further particulars should refer to Sir Lowthian Bell's most instructive and charmingly written paper on the "Manufacture of Iron and its Relations to Agriculture," read by him at the Liverpool meeting, in September, 1892, and inserted in the *Journal of the Iron and Steel Institute* of that year.

It is thus evident that, in Great Britain, there is only one-twelfth part of pig iron made by means of raw coal, and therefore the greatest bulk has to be made by means of coke.

It may be said that the quantity of coal made into coke in Great Britain, if the amount of coke consumed by furnaces, foundries, coke exported, and coke used by other industries is included, amounts to about 35,000,000 tons, and taking the yield at only 60 per cent., it may be estimated that 21,000,000 tons of coke is made, out of which about 20,000,000 tons are consumed in Great Britain. This yield of coke leaves the balance (14,000,000 tons) to be subdivided under the following headings: Three million five hundred thousand tons of ash, representing not less than 4,250,000 tons of shale or earthy matters, extracted from the coal before coking by the process of washing, while the balance, 9,750,000 tons, is represented by volatile matters—hydrocarbons and nitrogen. The process of separating the volatile matters from the fixed carbon is popularly known as coking, and takes place in appliances known by the name of coke ovens. The process itself, as carried on, mostly is a process of destructive distillation, and it takes place in an oxidizing atmosphere. The ultimate result of this mode of working is, on the one hand, coke, and, on the other hand, carbonic acid, carbonic oxide, and nitrogen, with a very small quantity of sulphuric acid.

The importance of the product obtained—the coke—is such that, however short a space I wish to devote to it, I am bound to describe the principal apparatus used for coking in Great Britain. Of these there are three, namely: (1) The Bee-Hive oven; (2) the Welsh or rectangular oven; and (3) the Coppée oven.

THE BEE-HIVE OVEN.

This consists of a round chamber, covered with a spherical dome, provided on the top with an opening for putting the coal inside the oven, and a front through which the coke is taken out—an operation known as "raking the oven."

The diameter of the oven is usually 12 feet, the height from the floor to the top of the dome being on an average 8 feet. The coal charged mostly remains under operation for forty-eight hours. It is lit on the top and in the middle of the circumference from the reflected heat of the arch, concentrated in the center of the upper surface of the coal, the other portions of the oven being at that time cold, owing to the fact that the coke is always cooled inside the ovens by water.

The coking starts on the surface, the gases generated being burned partly between the arch and the top of the charge; this space may be called the combustion chamber of the oven. The heat so produced in the combustion chamber of the oven propagates the coke from the center of the charge to the surroundings walls, at first in the upper layers, and propagates the coking downwards to the floor. That is why the whole charge is composed of pillars of coke, the length of which is the thickness of the charge. The top of each pillar is the top of the upper surface of the charge, and the foot of the pillar is the foot of the charge, or the surface of the charge touching the floor.

The coke, when cooled, preserves the silver appearance, but if a complete pillar is examined it will be found that the color grades slightly from the top to the bottom by getting darker and darker.

The portion of the pillar touching the floor generally is, if not black, very dark; that portion is called the "black foot." This gradation of color exists on account of the temperature, which gets lower as we get nearer to the floor.

It must not be lost sight of that the upper layer of the charge gets the full benefit of the heat produced in the combustion chamber, while the lower strata are separated from the combustion chamber by the upper crust of coke, which is a bad conductor of heat. The waste gases leave the oven through the charging hole into the air in some cases—I will say in most cases they are collected in a flue, which takes them down to the chimney, situated on the end of the block of ovens. Generally, before reaching the chimney, the sensible heat of these gases is utilized for heating boilers.

The air required for partial combustion of the gases is, as a rule, supplied in an adventitious manner—that is, by a hole made anywhere for that purpose, in the door or in the charging hole, or it leaks through the crevices of the oven.

It will easily be seen that the process, as described, is a slow one, and one leading to a waste of coke, consumed by the constant leaking of the air required for the combustion, so that the yields in coke are low.

It may be said here that some method has been contrived to improve these old-fashioned systems of ovens, viz.: by introducing the air into the oven at will, in quantities to be regulated, and, besides, by permitting the air to be superheated.

This last improvement, if carried out properly, increases the yield of the oven. The averages, from information which I have received regarding the weekly make and yields, referring to Bee-Hive ovens, are as follows: From 6 to 8 tons of coke are produced weekly, which yield in coke varying from 53 to 63 per cent. These last figures vary in accordance with the yield of coal in volatile matters, and also in accordance with the state of the oven and the care taken in manufacturing the coke. In spite of the defective points shown above, the Bee-Hive oven is the one which is most generally used, and, I dare say, I am not far out in stating that of the total yearly quantity of coke made in Great Britain 85 per cent. is made in Bee-Hive ovens.

THE WELSH OVEN.

This consists of a rectangular chamber, covered with a flat arch, and provided with a door on one end. The width of the oven is from 7 to 8 feet, the length from 13 to 15 feet, and the height does not exceed 5 feet. The oven is provided on the top with one or two charging holes, and in the front with a lifting door. One oven is separated from the next oven by a relatively narrow wall, not exceeding 2 feet thick. The back wall of the oven is also provided with an opening, through which the waste gases escape to reach the flue leading the same to the chimney, and before doing so very often are utilized for heating boilers.

These ovens receive the charge of coal from the top, which is properly leveled, and as within recent years, the cooling of the coke in the ovens has been abandoned, the charge is ignited by the reflected heat of the arch, and also by the transmitted heat through the relatively thin side walls separating the oven from its neighbors. The space between the arch of the oven and the charge constitutes a combustion chamber; the heat, therefore, generated in the combustion chamber acts directly on the charge. The middle portion of the batch of coke is therefore produced in a similar manner as in the Bee-Hive ovens, while the two side portions of the coke are produced by the transmitted heat of the side walls, and consequently the side coke does not have a pillar shape, but a conical one, very often called cauliflower.

These ovens are, I may say, exclusively used in South Wales, and they produce about 10 per cent. of the total quantity of coke made in Great Britain.

The process is by no means faster than in the Bee-Hive oven. The average make per week in these ovens may be taken at 6 tons 5 cwt., and the yield can be put down at from 58 to 60 per cent.

The air required is mostly supplied to them in the same manner as in the Bee-Hive ovens, and it could also be improved in a similar manner. In a few places these ovens have been flued under the floor and in the side walls, and then, although the make is higher and the yield better, they, as a rule, do not last long, and require a great deal of repairs. They are consequently gradually falling into disuse, and generally the Coppée ovens take their place.

THE COPPÉE OVEN.

This consists of a long, rectangular, narrow chamber, provided with a flat arch, on the spring of which are situated on each side of the oven twenty-eight openings. Each side wall is provided with twenty-eight vertical flues, their starting point being the twenty-eight openings just mentioned, and their end at the horizontal flue situated under each oven.

Some twenty-eight years ago, when this oven was invented, two ovens were working together, or, in other words, they were connected. Now, instead of having two, we have four ovens connected and working together. In other words, this means one oven in four compartments.

I will dispense with describing the oven minutely, not wishing to occupy your time with too many details.

Below the flues under the floors there is a series of horizontal flues for heating the air. They receive the cold air here from the outside, and deliver the hot air into a vertical shaft, which again delivers it into two horizontal flues situated on the top of the oven at right angles to their axis, while two flues deliver the hot air into each side wall. Each oven is provided with three charging holes situated on the top, and two doors, one on each end of the oven.

The usual length of the oven is 30 feet; the width varies from 17 inches to 2 feet, according to the class of coal treated; so does the height, which varies from 4 feet to 6 feet 6 inches.

Assuming that the oven is red-hot, the coal is charged into it by the three charging holes, and after being leveled and the doors closed, the charge ignites on the top. The gases are very abundantly generated, not only by the direct heat produced between the top of the arch and the top of the charge, but also by the transmitted heat of the two side walls and the floor of the oven. The gases generated escape with great facility from the oven through the fifty-six openings situated by springs of the arch, and enter the side walls, where, mingling with the hot air, they burn, and restore to the side walls the heat that has been taken from them by the introduction of the new charge of coal.

Four ovens are connected together, and as each of these are charged very nearly at equal intervals, it means a new spurt at equal intervals for each of the four ovens coupled together. The heat of the gases escaping from the oven must be pretty well exhausted, considering that the total section of the flues in each side wall is equal to some 1,000 square inches, which faet allows the gases to travel at a low speed, and consequently to give a chance to the brickwork to absorb the heat carried by them.

The mode of operation having been described, it will be plainly understood that the batch of coke coming out of the oven has the shape of a rectangle resting upon its small base. The vertical section of a batch decomposes in two trapezoidal parts and two triangles. One triangle is the lowest portion of a batch, the base of which is the width of the oven and the apex of which is about 10 or 11 inches from the floor, and upon the axis of the oven.

The second triangle is the upper portion of the batch, the base upwards and apex downwards, the base being also the width of the oven and also the top of the batch.

These two trapezoids are symmetrically situated; the wide bases of both are the side walls, and the small bases are the line of axis of the oven connecting the two apexes, as described above.

Each of the four parts decomposes eventually into a series of triangles in the vertical section. Practically the whole batch decomposes into a number of cauliflowers. The mathematical regularity of a section of a batch shows immediately if any oven is in good working order or not. The working of the ovens, therefore, is excessively rapid, and this shows itself by the fact that the weekly make per oven varies from 11 tons 15 cwt. to 15 tons. The yields vary from 56 per cent. to 78 per cent., according to the quality of the coal. The coke is cooled outside the ovens; therefore, the color of the coke is not so bright as the Bee-Hive oven coke. As to the moisture in the coke, it becomes simply a question of care in the manufacture to keep the moisture down.

UTILIZATION OF VOLATILE PRODUCTS.

It has already been stated that 9,750,000 tons represent the volatile matters—hydrocarbons and nitrogen. Going back thirty years, it will be found that the greater portion of the volatile matters, except that which partly burnt in the ovens, causing the coking, was wasted. Now, however, in most cases this is not the case, as what is not burnt in the ovens is utilized, to a certain extent, for boiler heating purposes.

In order to show approximately how the 9,750,000 tons of volatile matters are disposed of, the first and most important point will be to estimate the equivalent of those gases in coal; and then to find the quantity of those gases by its coal equivalent consumed in the ovens for the purpose of coking. After finding this, there will be a balance left to the good, which

will show the heating power of the gases left, and ultimately show the number of boilers to be heated by them, and the horse power to be produced.

In order to solve this first portion of our query, it is necessary to borrow certain figures to be found in *Stahl und Eisen*, in the article entitled "Entwicklung und Gestaltung der Koksindustrie durch die Verwerthung der Nebenerzeugnisse," by Mr. B. Leistikow, 1892, pages 818–826. The figures are as follows: One hundred cubic meters equal to 3,500 cubic feet, equal to 37.6 pounds weight of gas, taking 0.4 as being the specific density of the gas at a temperature of 0° C. and atmospheric pressure. This is equal as heating energy to 193 pounds of coal.

Knowing that 37.6 pounds of gas are equivalent to 193 pounds of coal as heating energy, I find that one pound of gas equals 5.13 pounds of coal, and one ton of gas is equal to about 5 tons of coal. Consequently, I find that 9,750,000 tons of gas equals about 50,000,000 tons of coal. Knowing further, that in order to generate the gas out of a ton of coal about one-fifth of the equivalent found in coal is required for the coking process itself, while four-fifths are to be utilized in the present state of the coking manufacture for generating steam, the four-fifths give 7,800,000 tons of gas, or their equivalent in coal of 40,000,000 tons.

Assuming that a pound of coal evaporates 6 pounds of water, in practice, there is evaporated 240,000,000 tons of water; and knowing, also, that 36 pounds of steam are required to produce one horse power, it is seen that about 7,000,000 horse power will require about 100,000 Lancashire boilers of 7 feet 4 inches diameter, each capable of generating 60 horse power. Roughly speaking, there are 2,000,000 coke ovens in this country to generate this power, which would mean 20 coke ovens per each boiler. Knowing, on the other hand, that the greatest number of ovens used for heating a boiler is 15, the number of ovens required for heating the above number of boilers would be 1,500,000, so that assuming there are 100,000 boilers heated by coke ovens, there would be half a million of ovens wasting their gases, which would mean a waste of gas equal to one-fifth of the quantity to be utilized for heating purposes, and expressing it in the equivalent of coal, would mean 10,000,000 tons of coal wasted yearly.

Expressing now the value of gases utilized and wasted in money, we find that putting the price of 3*s*. per ton of coal, representing the equivalent of one-fifth of a ton of gas, the value of the gases that could be utilized is £5,000,000, and the value of gases wasted is £1,000,000.

I have assumed that 100,000 Lancashire boilers are in operation in connection with coke ovens. I have had no opportunity to verify this, but I am under the impression that the number is nearer half of the figure, and the value utilized will not exceed £2,500,000, and the value wasted £3,500,000.

I have shown just above how the waste gases are utilized, and to what degree; also the value of them.

The way of utilizing the gases in that manner, as described, for a long time was recognized as not being satisfactory—as far as forty years—the first efforts having been made in Belgium and France to save them from destruction, in order to extract from them ammonia and tar.

No doubt, the gas works practice of extracting tar and ammonia has been an example to the coke manufacturer; equally has it been so to the Scotch ironmasters in their blast-furnace working. The first efforts, however, in that direction have not at all been a success. The coke was of very poor quality, and the by-products difficult to dispose of. We must remember that only about thirty years ago the usual way in which the gas works could get rid of their tar was by burning it as fuel, while the ammoniacal liquors passed into the sewers.

It is only ten years back, and not more, that the question of saving the by-products in the coking process was revived. The public interest in the matter was very great, and a series of interesting and instructive papers were read before this institute on the subject by (among others) Prof. Watson Smith and by Dr. Otto, followed by very interesting and exhaustive discussions. Prof. Watson Smith has illustrated his paper with all the systems of ovens at the time invented for the purpose of collecting by-products. I see my own name among a series of others as a patentee of an oven designed for that purpose. The meeting was held in Middlesborough, and the members visited, I remember, a batch of ovens erected by Messrs. Simon-Carvès for Messrs. Pease and Partners, at Crook.

Dr. Otto, in Germany, I do not think at that time had any of the Coppée-Otto ovens in operation. However, he has made very rapid strides since, as within the last few years he has erected, up to 1892, 470 ovens in Westphalia, 705 in Silesia, and 30 in the Saar district, while on the other hand, in Great Britain very little has been done. The total number of by-product ovens in use, I am certain, does not exceed 200, and this includes 40 ovens of the Semet-Solvay type at the works of Messrs. Brunner, Mond & Co.

I do not propose to describe in detail the Simon-Carvès ovens, nor Coppée-Otto ovens, nor Solvay's, because they have been fully described and illustrated before.

I wish, however, to say that during the period of ten years I have taken a great deal of interest in the subject, and tried to contrive an oven which has qualities that others have not. Dr. Otto's installations in Germany, which are certainly the most complete among those that exist, are very costly on account of the whole condensing plant being duplicate for obvious reasons, viz., in the case of something going wrong with the condensing plant, the whole concern would be stopped, and consequently the original trifling cause may lead to a great deal of trouble and loss.

The principal feature in the oven that I propose is that the gases are not drawn direct from the oven, as in general practice, but from a flue situated in the top of the side wall on each side of the oven. This flue, by means of two dampers situated one on each end of it, may be at will connected or disconnected from the flues situated inside of the side walls, so that when the two dampers are in their normal position the oven is working as a closed vessel, and the gases are drawn to the condensing plant at first. If, however, for any cause it is necessary to turn the oven into one working in the presence of the oxidizing atmosphere, the dampers are shifted, and the burning gases are admitted into the side walls first, under the floor after, and ultimately into the main flue.

Before going any further, as I do not wish to hurt any one's susceptibility, I must say that I have deliberately omitted the Bee-Hive oven, with all its so-called improvements with reference to by-products, because even if I felt the greatest sympathy with that class of ovens, which I do not, I could not rationally admit any such alteration or improvement which would have an object of getting by-products not equal (and in reality they are inferior) in quality to those obtained from the Simon-Carvès, Coppée-Otto ovens, or any other of that class. The importance of extracting tar and ammonia, in the shape of sulphate of ammonia, from the gases, has been shown by Sir Lowthian Bell in his admirable paper on "Manufacture of Iron and its relation to Agriculture." We all know that the vegetable world lives to a great extent on nitrogen, and although the air we breathe contains 75 per cent. of nitrogen, the plants and trees do not assimilate it as such—that is to say, the vegetable world does not take the nitrogen directly from the air, and the nitrogen has to be dished up for them as sulphate of ammonia or ammonia, and it is only as such assimilated by them. This is the theory of the famous Dr. Liebig. It has been found by Dr. Otto, who has constructed, as stated above, the largest number of by-product ovens, and who uses the most complete condensing plant, that one ton of coal gives 25.54 pounds of sulphate of ammonia, plus 60.84 pounds of tar.

I have stated that in Great Britain 35,000,000 tons of coal are made into coke. Therefore, about 400,000 tons of sulphate of ammonia and about 900,000 tons of tar are lost to the community. Putting the sulphate of ammonia at the present price of £10 10*s.* per ton, we get the value of £4,-200,000. Deducting from this amount 33 per cent. for working expenses, it leaves as net value £2,800,000. Putting the value of tar at 32*s.* 6*d.* per ton, we obtain £1,462,500. Therefore we waste yearly £4,262,500.

Further, it is stated that after the condensation of gases—that is to say, extracting tar and ammonia and utilizing the heat required for the ovens—sufficient heating power is left in the gases to the extent of being able to evaporate not less than one ton of water per every ton of coal charged into the ovens, and by gases otherwise escaping. The heat required for coking purposes is the same here as what is wanted in ordinary coking. This I

have estimated to be equal to 1,950,000 tons of gas, or equal to 10,000,000 tons of coal.

The gas efficiency here, as said before, remains only very slightly altered, and we make out that the heating power of those gases is worth about £1,500,000, so that the total value of waste in this case will amount to £5,762,500.*

I do not wish you to be under the misapprehension that, as nothing has been said about the quality of coke, I am timid on that subject, especially knowing that very likely the majority of you are in favor of Bee-Hive-oven coke. In my opinion, the quality of coke made in Coppée ovens, or in by-product ovens, if not superior, is equal in all respects to Bee-Hive coke.

There is very little doubt in my mind that the heating power of the gases of ordinary coking could be utilized in more than one way, and it occurs to me that it could be utilized, for instance, for the destruction of solid sewage; and I do not see why in large mining centers, where the population is very dense, and where a large number of coking installations are in existence, the waste heat could not be utilized for sanitary purposes. It is so much more important as the moisture in the solids, which carries a great deal of ammonia with it, could be collected and made into sulphate of ammonia and utilized for fertilizing purposes.

Some years back I made some experiments with reference to this matter, so that I am not speaking on the subject as altogether a stranger to it.

The following is a general tabulated statement exhibiting, in full details, the number of the Bernard narrow ovens now in successful operation, with the qualities of coal used and the coke produced from this oven.

(This oven is not specially designed for the saving of by-products in coking.—Ed.)

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*It should be noted that the gases resulting from this mode of coking, and after their cooling for the purpose of extracting tar and ammonia, may be expected at any reasonable distance to yield their heating efficiency. In most respects they are much superior to the waste heat resulting from ordinary coking. Therefore, could they not be utilized at a distance and create power where it is wanted? It is also to be considered if the coking should not with advantage be located, not near the collieries, as at present, but nearer the large centers of population, where their energy could easily be utilized.

LIST OF RETORT COKE OVENS—CL. BERNARD'S SYSTEM, BUILT SINCE 1887.

Representatives of Mr. Cl. Bernard, Bruxelles, Belgium and France.
Walter M. Stein, Philadelphia, Pa., United States, Canada and Mexico.
Emilio Dury, Bilbao, Spain.
Peckala Frères, Ekatherinoslaw, Russia. **4, 1, 1894.**

NAME AND LOCATION OF COMPANIES HAVING BERNARD COKE OVENS.	Number of Ovens.	Time of Coking.	Daily Output Per Oven. Net Tons.	Nature of Coal Used.	Volatile Matter in Coal Used.
BELGIUM—Société des Charbonnages du Midi de Mons	30	48 hrs	2.93	Unwashed.	25-26%
" " " de Maurage près Mons	96	24 "	2.75	"	15-16%
" " " du Horloz à Villeur	20	24 "	2.75	"	17-18%
" " Hautes furneaux de Monceau s/Sambre	40	24 "	2.75	"	18-19%
" " " " de Sclessin	100	24 "	2.75	"	14%
" " Charbonnages du Bois d'Avroy	60	24 "	2.69	"	14%
" " " de Maritrage	32	48 "	2.92	Washed.	20-22%
Total 373					
FRANCE—Compagnie des Mines de L'Escarpelle	72	48 "	2.75	Washed.	20%
" " " " "	128	24 "	2.75	"	20%
" " " " Noeux	20	48 "	2.75	"	21%
" " " " Dourges	20	48 "	2.75	½ washed / ½ unw'hed	23-24%
" " " " Aniche	40	24 "	2.64	Washed.	21%
" " " " Ferfay	16	48 "	2.75	½ washed / ½ unw'hed	28-29%
Société des Aciéries de France à Isbergues	36	24 "	2.76	Washed.	23%
" " " " " à Aubin	20	24 "			
" " " " (La Marine) L'Arlous à Bonceau	40	24 "	2.75	Unwashed.	23%
" " " " Demain à Anzin	32	24 "	2.76	"	23%
Compagnie des Mines d'Auzits (Aveyron)	20	24 "	2.31	"	24%
" " " de Campagnac (Crausac)	26	24 "	3.3	"	31-33%
Total 470					
SPAIN—Mines de Aller à Uyo (Asturia)	40	48 "	2.75	Washed.	24%
Co. Houillière de Belmez à Perarroya	24	24 "	2.64	"	22%
Co. Carbonifera de Matallana à Bilbao	24	48 "	2.75	"	24%
Sur. Fernandez Mines de Figaredo	12	48 "	2.43	"	33%
Sur. Martinez de las Rivas à Bilbao	90	24 "	2.64	Unwashed.	24%
Total 190					
RUSSIA—(Since 1892-93) Co. des Forges & Aciéries du Donetz-Droykowka.	42	48 "	2.75	½ washed.	25%
Co. de Goloubouka à Khetrkoff	48	48 "		½ unwashed.	
Mor. D. Glovalsky à Charzishala	42	48 "			
Total 132					
AMERICA—CANADA—(1892) New Glasgow Iron, Coal & Railway Co.—Ferrona, N. S.	36	40-48 "	2.75	Washed.	23%
(1893) New Glasgow Iron, Coal & Railway Co.—Ferrona, N. S.	18	40-48 "	2.75	"	23%
Total 54					
AUSTRIA—Mess. Vondracek-Mähr Ostrau... " 30	30	24 "	2.97	Washed.	16%
Grand Total.. 1,254					D 4.

The following table shows in great detail the work of the Seibel retort coke oven in making coke and saving the by-products of tar and ammonia sulphate.

This oven has horizontal flues with means of regulating its heat so as to intensify it at the upper section of the oven chamber during the initial process of coking, the heat is then increased downwards in the oven, securing a maximum deposit of carbon from the gas evolved in coking.

Copy of Results at
Compagnie des Mines
de
Campagnac,
With Coke Ovens with Saving of By-products.
System G. Seibel, Manager.

1st Quarter, 1885.
RESULTS FROM COKE OVENS.
18 Small Sized Ovens, 19′ Long.

Society for the Construction of Coke Ovens.
Cl. Bernard, Civil Engineer; G. Seibel, Manager
of the Compagnie des Mines de Campagnac (Aveyron).
Ordinary Coke Ovens. with or without Saving of By-products.
Offices: Brussels, Rue d'Angleterre.
(Paris) Asnieres, Mr. Boucomont, Civil Engineer,
Avenue Flachat, No. 17.

Coal Charged Contains 30% to 32% Volatile Matter, 3,715 Gross Tons.

PRODUCTS.

	Quantity Obtained.	Average Selling Price.
	Gross Tons.	Fr.
Coke	2,972.70	19,378
Tar	114.61	35,416
Sulphate of Ammonia	16.00	318,440

COST OF LABOR.

Classification of Men Employed.	Days.	Wages.	Total Wages.	Total Cost.
Coking Cost. Foremen	91.50	3.93	360.00	6,398.52
Machinists	180.00	3.83	690.90	
Mechanics	188.30	4.38	825.19	
Ordinary Labor. Men	1,092.40	2.91	3,179.90	
Ordinary Labor. Women	698.20	1.49	910.80	
Ordinary Labor. Children	39.30	1.24	49.12	
Steam Fitter	87.70	3.00	263.10	
Repairs	39.40	3.02	120.41	
Tar-saving Cost	94.20	1.83	172.79	172.79
Labor in Making Sulphate of Ammonia	90.00	3.33	300.00	300.00
Total	2,601.00	2.64	6,871.81	6,871.81

MATERIALS USED.

Details of Materials Used.	Detail Cost.	Total Cost.	Total Expenses	Self Cost Per Ton.
Coking Cost. Wood and Planks	39.30	26,658.78	33,057.30	8.898
Iron Bars	98.10			
Ropes, Packing, etc	14.76			
Bolts, Shovels, etc	184.65			
Oil and Grease	69.62			
Baskets, Brooms, Tuyeres, Rubber, etc.	225.00			
Bricks and Lime	22.35			
Coal charged, 3,715 gross tons @ fr. 7.00.	26,005.00			
Barrels used for Tar	45.00	45.00	217.79	0.058
Manufacture of Sulphate of Ammonia. Sulphuric Acid, 17,479 k. @ fr. .1028.	1,797.65	2,083.85	2,383.85	0.641
Manufacture of Sulphate of Ammonia. Glass Tubes, Rubber, etc.	286.20			
Total	28,787.63	28,787.63	35,658.94	9.598

The Sale of the Products of Condensation gave	fr. 66,761.30	or per Ton	fr. 17.970
The Total Expenses were	35,658.94	" "	9.598
The Profits are	31,102.36	" "	8.372

W. M. Stein,
METALLURGICAL ENGINEER,
325 Walnut St., Philadelphia, Pa.

COPY OF RESULTS OF COMPARATIVE TESTS OF BERNARD'S & COPPÉE'S COKE OVENS MADE BY LA COMPAGNIE VICOIGNE ET NOEUX À NOEUX LES MINES (FRANCE—PAS DE CALAIS).

AMOUNT OF COAL CHARGED.				AMOUNT OF COKE OBTAINED.												
Date of Charging.	No. of Kilos (2.2 lbs.) of Coal Charged.		Volatile Matter.	Date of Discharge.	Weight of Marketable Coke.		Weight of Small Coke below 1½″.		Total Yield of Coke.		Percentage of Marketable Coke.		Percentage of Small Coke below 1½″.		Total Percentage of Coke.	
	Coppée Oven.	Bernard Oven.			Coppée.	Bernard.	Coppée.	Bernard	Coppée.	Bernard	Coppée.	Bernard	Coppée.	Bernard	Coppée.	Bernard
1889.	Kilos.	Kilos.	%	1889.	Kilos.	Kilos.	Kilos.	Kilos.	Kilos.	Kilos.	%	%	%	%	%	%
January 14	7480	7540	20.5	January 16	5390	5935	175	125	5565	6060	72.1	78.7	2.3	1.7	74.4	80.4
" 15	7300	7500	20.6	" 17	5280	5900	170	120	5450	6020	72.3	78.7	2.3	1.6	74.6	80.3
" 16	7530	7550	20.6	" 18	5535	5920	160	118	5695	6038	73.3	78 4	2.1	1.6	75.4	80.0
" 17	7250	7500	20.4	" 19	5270	5950	180	120	5450	6070	72.6	79.3	2.5	1.6	75.1	80.9
" 18	7250	7530	20 5	" 20	5270	5930	175	125	5445	6055	72.7	78 8	2.4	1.7	75.1	80.5
" 19	7100	7100	19.5	" 21	5150	5629	170	110	5320	5739	72.5	79.3	2.4	1 5	74.9	80.8
	Kilos.	Kilos.	Average		Kilos.	Kilos.	Kilos.	Kilos.	Kilos.	Kilos.	Average	Average	Average	Average	Average	Average
Total....	43910	44720	20.36%		31895	35264	1030	718	32925	35982	72.64%	78.85%	2.35%	1.61%	74.99%	80.46%

W. M. STEIN,
METALLURGICAL ENGINEER,
825 Walnut St., Philadelphia, Pa.

Certified: Noeux, January 25th, 1889.
The Director of Mines,
per Gérard Mulheim.

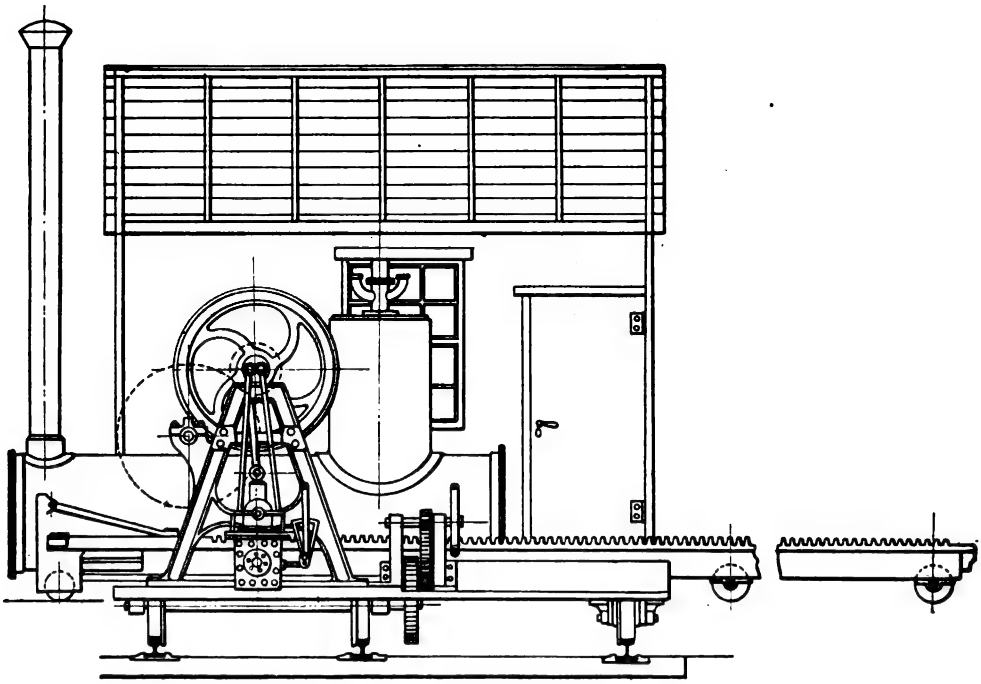


FIG. 87.—COKE PUSHING MACHINE (RAM) FOR RETORT COKE OVENS. MADE WITH OR WITHOUT BOILER, VERTICAL OR HORIZONTAL ENGINE.

STANDARD SIZES.

No.	Diam. of Cylinder.	Stroke.	Weight With Boiler.	Weight Without Boiler.	Price f. o. b. Phila.
I. Vertical.	10″	11″	20,834 lbs.	17,160 lbs.	....
II. "	12″	10″	....	25,300 "	....
III. "	14″	12″	30,690 lbs.	....	....
IV. Horizontal.	10″	12″	18,700 "	13,200 lbs.	....
V. "	12″	17⅜″	33,726 "	....	$3,750

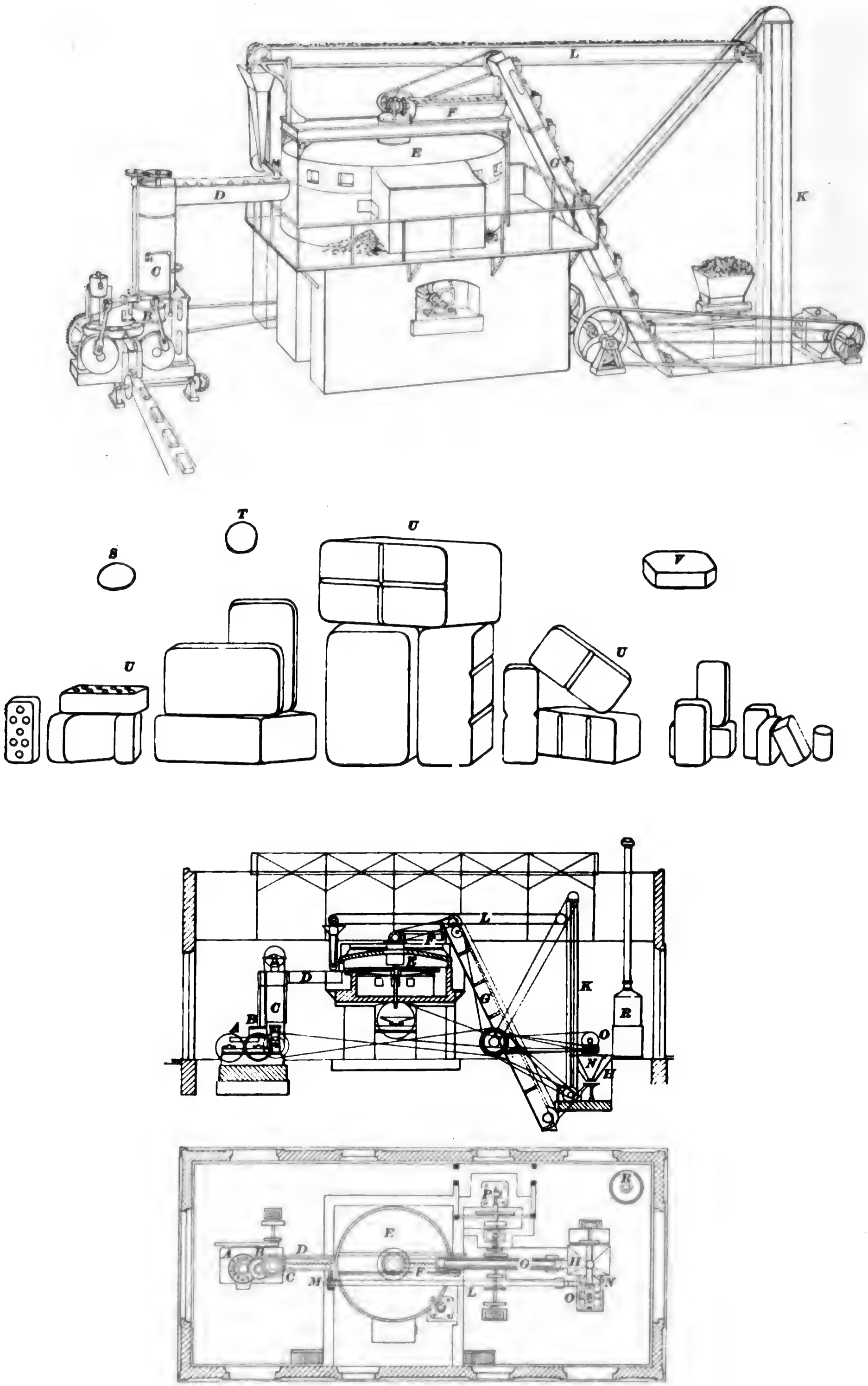


Fig. 88.—BRIQUETTE MAKING MACHINE.

W. M. Stein, Metallurgical Engineer, Philadelphia, Pa.

A, Briquette Making Machine.
B, Filling Hopper.
C, Mixer.
D, Screw Conveyor.
E, Rotary Heating Furnace.
F, Screw Conveyor for Coal.
G, Elevator for Coal.
H, Coal Hopper.
I, Disintegrator.
K, Elevator for Pitch.
L, Pitch Conveyor Band.
M, Pitch Conveyor.
N, Pitch Hopper.
O, Pitch Grinding Mill.
P, Steam Engine.
R, Boiler.
S, Eggette ¼ to ⅛ lb.
T, Boulette.
U, U, Briquettes.
V, Lignite Briquette, 6″ long, 2¼″ wide, 1½″ thick; weight, ⅜ lb.

DIMENSIONS OF BUILDINGS.

	For Pressing Machines for			
	2⅛ lbs. Briquette.	6⅛ lbs. Briquette.	11 lbs. Briquette.	20 to 22 lbs. Briquette.
Length	60 ft.	70 ft.	83 ft.	93 ft.
Width	28 "	30 "	35 "	37 "
Height	18 "	18 "	22 "	22 "
Production in 10 hours.	20 tons.	50 tons.	80 tons.	150 tons.

BENZOLE CARBURETTING APPARATUS.

The benzole carburetting apparatus for the enriching of illuminating gas with benzole, built at Munich upon the theoretical lines of Drs. Bunte, Shilling and Ries, is designed to increase the illuminating power of gas to any desired degree, limited only by the carburetting power of the materials employed. The best material for carburizing in this system is benzole of a specific gravity of from 0.85 to 0.88, such as is obtained from the distillation of tar and from the by-product plants of coke works. This benzole is not only the best but the cheapest carburetting fluid. The apparatus, however, may be used with other carburizing materials.

In enriching by this method, especially with benzole, the illuminating power may be increased to any desired degree without reference to the coal utilized, the temperature maintained in the benches or their method of operation by the workmen. The illuminating power of the gas may be increased to 16 candle-power, such as is supplied in most cities, or to a still higher candle-power as is shown in attached tables in which are given the working limits of the apparatus. The consumption of benzole in this apparatus is ascertained from the amount of gas to be enriched and by the degree of enriching necessary to give the desired candle-power. The results obtained by the investigation of the three gentlemen named above can be relied upon as being practically correct. These results show that four grams of benzole will raise one cubic meter of gas one Hefner-light. This is practically equal to two and a half grams of benzole to raise one cubic foot of gas one candle-power. Of course it is necessary in all cases to determine beforehand the candle-power of the gas to be carburetted.

Carburetting Apparatus at Munich.—The complete carburetting plant, as made by the Berlin-Anhaltische Maschinenbau-Actien-Gesellschaft, ready to connect with the main of the gas works, consists of a special carburetting apparatus *A* (see Fig. 89), the storage tank *B*, with the charging apparatus

and an indicator composed of a regulator and the necessary connecting pipes. The special evaporation apparatus A, consists of a rectangular box with movable lids into which special shaped ribbed plates with a slight pitch are inserted over which the benzole flows in a thin sheet. The gas enters at G, passing in an opposite direction to the flow of the benzole so that the

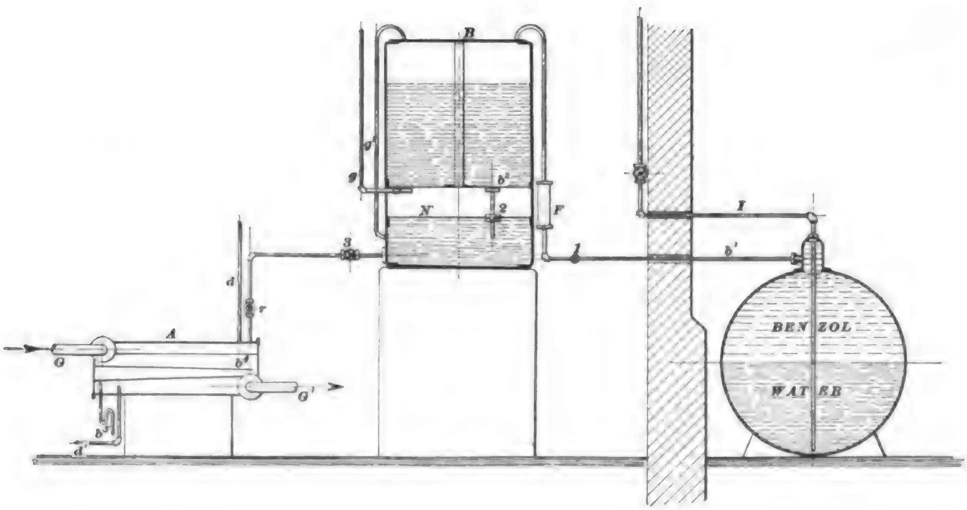


FIG. 80. BENZOLE CARBURETTING APPARATUS.

most intimate contact takes place between the benzole and gas. The enriched gas leaves the apparatus at G^1 to be mixed immediately with the uncarburetted gas. The benzole enters by b^4. At b^5 is a test cock to ascertain if any unabsorbed benzole is left in the apparatus. A steam heating apparatus is so arranged as to produce the temperature necessary for evaporation, which is especially needed during the winter time and also to replace the heat absorbed by evaporation. The steam, which enters at d and leaves at d', by its heat increases the capacity of the apparatus very considerably, so that a very small apparatus will have a very large carburetting capacity. The storage reservoir B serves to hold the benzole necessary to supply the apparatus. The capacity of the reservoir B in the apparatus shown is 500 kilograms (1103 lbs. or 155 gals.) of benzole, enough to supply the apparatus shown, which is the one employed at Munich, for at least one day. The flow of the benzole into the carburetting apparatus is always under uniform pressure so that the supply, being once regulated at the beginning of the operation, continues the same during the whole process. To secure this result, that is, to keep the benzole always at the same level N, special mechanism is provided. B is a completely closed vessel constructed with a double bottom. Benzole is forced out by gas which enters through pipe g into the spaces between the bottoms, avoiding thereby danger by fire, since the benzole circulates in inclosed

spaces and is never brought up in contact with air, thus avoiding entirely the generation of explosive mixtures. By opening cock 3 benzole flows from the lower vessel to the carburetting apparatus, but before the level N can drop, gas enters the storage tank B by the connecting pipe g^1, causing so much of the benzole to flow through the pipe b^2 as is necessary to again seal the connecting pipe g^1 by the raising of the benzole to the level N. The flow of benzole from the storage tank is, therefore, always under uniform pressure. To fill the tank B, providing the benzole is brought to the works in barrels, the process is as follows: The cock 2 is closed, a double pipe is screwed into the bung hole of the barrel, connecting it with the city water pressure through one pipe, and with the benzole supply b^1 through the other. Then by opening the water cock the water pressure drives the benzole from the barrel through the open cock 1 into tank B, causing the gas to flow back into the gas main through g^1 and g. A large closed water tube is inserted at F so that the division between the water and benzole can be seen as soon as the benzole is all forced out of the barrel. As soon as the water appears at F the cock 1 is closed. If the benzole is to be supplied to the apparatus from large masonry cisterns it will be necessary to pump it into B.

The indicator at B shows on one side the capacity of the tank by liters or barrels, and on the other side the capacity by weight for benzole of a specific gravity of 0.85 to 0.88. The actual amount of benzole may be ascertained at any time. The supply of benzole, as well as the working of the entire apparatus, is regulated by the regulating cock r, to which is attached a graduated circular scale, so that the proper amount of benzole can be supplied for any amount of production of gas per hour. The divisions on the scale indicate the amount of benzole in kilos per hour that will flow into the carburettor, and it is only necessary to find out how much benzole is needed to carburated the gas produced per hour and to set the cock to the point shown on the graduated scale for this amount of benzole. In order to successfully enrich the gas, and at the same time to avoid a waste of benzole, the required number of Hefner-lights or candle-power which must be added to the unenriched gas in order to raise it to the required candle-power must be first photometrically ascertained. Having ascertained this, as it requires four grains of benzole to raise one cubic meter of gas one Hefner-light, it is easy to ascertain the quantity of benzole in kilograms needed per hour for the use of the apparatus, and the regulating cock may be set to furnish this amount. If the production of gas at a gas works amounts, say, to 200 cubic meters per hour, and the illuminating power of the unenriched gas is 12 Hefner-light and

16 Hefner-light is required, then $\frac{4 \times 4 \times 200}{1000}$ equals

3.2 kg., which is the amount of benzole that must be supplied per hour, and the regulating cock must, therefore, be set to 3.2. The production of gas

at the gas works, with the exception of slight fluctuations, only changes at long intervals and only in case when new benches are lighted. Therefore, with but little difficulty the needed additional supply of benzole can be controlled by the cock. Any other mechanical device for this purpose could only complicate the apparatus and render it unsafe for operation.

Erection and Starting of the Apparatus.—The carburetting apparatus may be connected to any of the main pipes at a point where the gas would be entirely free from tar. This can be best accomplished by a by-pass by which a sufficient amount of gas may be passed through the apparatus to absorb the benzole supplied, the rest of the gas being allowed to pass under the partially closed by-pass valve. Whether the quantity of gas which is enriched is sufficient to enrich the entire amount of gas can be ascertained at the outflow b^5, the test being that no benzole escapes. The apparatus is operated only at low pressure, and particular attention must be given that the over-saturated gas on leaving the apparatus is forced back by the shortest route to the main supply in order to avoid a separation of the benzole from the gas. The erection of a carburetting apparatus parallel with the city pressure regulators, which would enrich the gas during certain hours of the day, is not recommended, since by this method the enriching of the gas would be subject to the fluctuations in the consumption of gas, necessitating the use of unnecessarily large and unproportioned quantities of benzole during the night hours, which would cause difficulty in the regulation of the supply of benzole. If gases of different candle-powers are required it is best to produce and store them separately.

In beginning operation the benzole tank must be first filled. The apparatus is then warmed by steam. Inlet and outlet cocks for the gas are opened and those in the main pipe so set as to drive the gases through the carburetting apparatus. It is important to force as large a quantity of gas as possible through the carburettor. In every case enough gas must pass through the apparatus to completely absorb the benzole supplied, so that none of it can leave by the test cock.

Capacity of the Apparatus.—The capacity of the different sizes of apparatus made is shown in table I.

Table I.—LARGEST CAPACITY.

NO. OF APPARATUS.	WITH STEAM HEAT.							WITHOUT STEAM AND A TEMPERATURE OF THE GAS NOT BELOW 18° C,* = 64° F.						
	Benzole Evaporated Per Hour.	Total Amount of Gas Produced Per Hour to be Enriched.						Benzole Evaporated Per Hour.	Total Amount of Gas Produced Per Hour to be Enriched.					
	kg.	1 HL cb. m.	2 HL cb. m.	3 HL cb. m.	4 HL cb. m.	5 HL cb. m.	6 HL cb. m.	kg.	1 HL cb. m.	2 HL cb. m.	3 HL cb. m.	4 HL cb. m	5 HL cb. m.	6 HL cb. m.
I...	8,000	2,000	1,000	650	500	400	300	2,500	650	350	200	170	130	100
II...	12,000	3,000	1,500	1,000	750	600	450	4,000	1,000	500	300	250	200	150
III...	16,000	4,000	2,000	1,300	1,000	800	600	5,500	1,300	700	400	340	260	200
IV...	24,000	6,000	3,000	1,950	1,500	1,200	900	8,000	2,000	1,000	650	500	400	300

* Note.—For lower temperatures the capacity is correspondingly lower.

In general it is to be observed that the capacity of the apparatus may be increased during winter time by steam-heating, so that an apparatus enriching during summer time without steam 250 cb. m. per hour, will, during winter time, with steam heat, enrich 750 cb. m.

The dimensions of the apparatus are shown in table II.

Table II.—DIMENSIONS OF THE APPARATUS.

NO. OF APPARATUS.	Benzole Evaporated Per Hour.	SIZE OF		No. of Iron Plates.	STEAM PIPE.		BOX.			Diameter at the Entrance and Exit.	Smallest Inner Section of Passage.
		Evaporating Surface	Heating Surface		Length.	Diameter.	Length.	Width.	Height.		
	kg.	sq. m.	sq. m.		m.	m.	m.	m.	m.	m.	sq. m.
I.........	8,000	1.4	1.4	3	26	0.009	1.250	0.400	0.470	0.100	0.024
II.........	12,000	2.4	2.3	5	44	0.009	1.250	0.400	0.770	0.100	0.024
III.........	16,000	3.4	3.2	7	60	0.009	1.250	0.400	1.070	0.150	0.024
IV	24,000	4.3	4.1	9	80	0.009	1.250	0.400	1.370	0.175	0.024

Dimensions for the storage tank with arrangement for a uniform supply of benzole, also connections and ducts are not given, since the same depend in each case upon the amount of gas to be kept in storage, and also upon the place of its erection.

To ascertain whether the cost of benzole at the works exceeds that of coal for carburetting is shown by the following formula:

$$B = \frac{100{,}000}{b\,a\,(i - i')} \times (P + m - K);$$

B is the price for benzole per 100 kg. at works.

P, the cost of 100 kg. cannel coal at works.

K, the cost of 100 kg. gas coal at works.

i, illuminating power of the gas from cannel coal.
i', illuminating power of the gas from gas coal. } in Hefner-light.

(Measured under same conditions.)

a, the yield in gas from 100 kg. of the gas coal in cb. m.

b, the quantity of benzole needed to raise 1 cb. m. of gas 1 Hefner-light (measured under the same proportions as i and i') in grams, (mostly 4 gr.).

m, the lowest value of products from 100 kg. cannel coal compared with that from 100 kg. of gas coal.

m is derived from the following formula:

$m = gG + cC + lL + tT$ if the difference in the yield is indicated for

Gas	by g;	the	net profit	per 1 cb. m.	by	G	in MK.
Coke	by c;	"	"	per 100	"	C	"
Breeze	by l;	"	"	"	"	L	"
Tar	by t;	"	"	"	"	T	"

The co-efficients g, c, l, t, can be taken from the following table for mixtures of coal chiefly used in Germany:

Material used in producing gas.	Value for g.	c.	l.	t
I.				
1. Saar coal and Cannel coal	3.7	0.134	—0.774	—0.033
2. Westphalian "	3.8	0.187	—0.071	—0.059
3. Saxony "	—1.0	0.096	—0.071	—0.054
4. Silesian "	4.2	0.151	—0.061	—0.050
5. Bohemian "	0.8	0.054	—0.035	—0.037
6. English "	0.8	0.188	—0.078	—0.056
II.				
1. Saar coal and Platten coal	—0.3	0.129	—0.024	—0.034
2. Westphalian "	—0.2	0.182	—0.021	—0.060
3. Saxony "	—5.0	0.091	—0.021	—0.055
4. Silesian "	0.2	0.146	—0.011	—0.051
5. Bohemian "	—2.7	0.049	—0.015	—0.038
6. English "	—3.2	0.183	—0.028	—0.052
III.				
1. Saar coal and Brown coal	—1.4	0.597	—0.279	—0.125
2. Westphalian "	—1.3	0.600	—0.276	—0.151
3. Saxony "	—6.1	0.559	—0.276	—0.146
4. Silesian "	—0.9	0.614	—0.266	—0.142
5. Bohemian "	—3.8	0.517	—0.240	—0.129
6. English "	—4.3	0.651	—0.283	—0.148

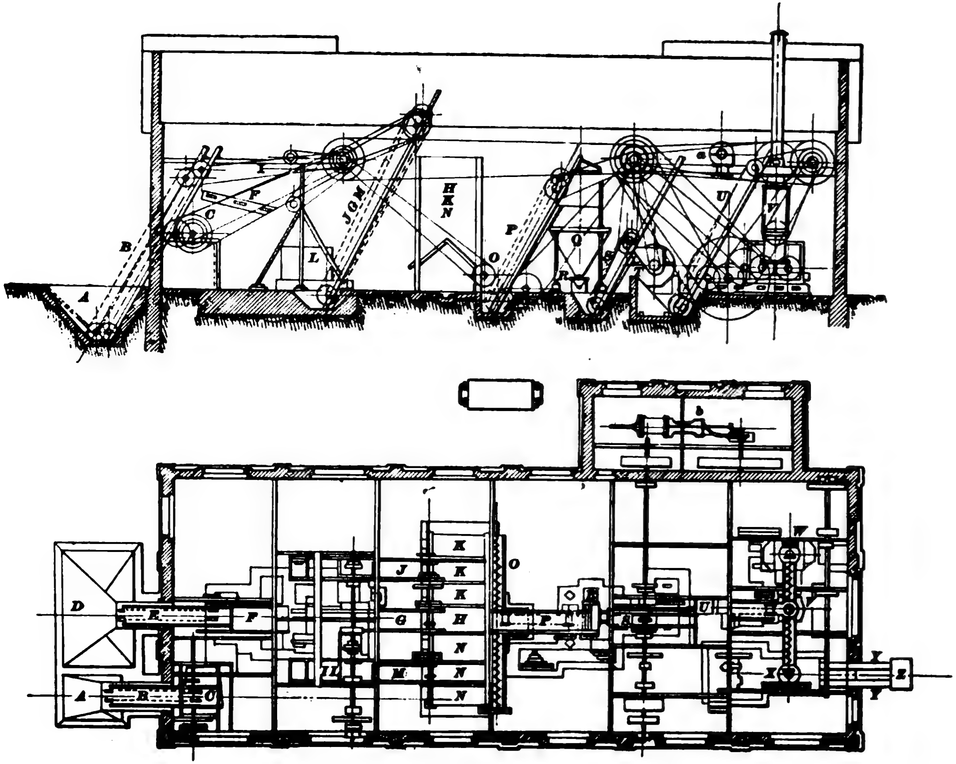


Fig. 90.

Separating & Coal Washing Plant with

Briquette & Eggette Press.

Capacity in 10 hours $\left\{ \begin{array}{l} \text{120 Tons Briquettes \&} \\ \text{50 " Eggettes.} \end{array} \right.$

A	Dumping Pit.
B	Bucket Elevator.
C	Screen Drum.
D	Dumping Pit.
E	Bucket Elevator.
F	Shaking Screen.
G	Bucket Elevator.
H	Storage Tower.
I	Washing Machine for ¼″ to ⅛″.
J	Bucket Elevator.
K	Draining Towers.
L	Washing Machine for ⅛″ to 1″.
M	Bucket Elevator.
N	Draining Towers.
O	Conveyor Screw.
P	Bucket Elevator.
Q	Balloon.
R	Mixer.
S	Bucket Elevator.
T	Carr Disintegrator.
U	Bucket Elevator.
V	Mixer.
W	Eggette Press.
X	Briquette Press.
Y	Conveying Bands for Briquettes.
Z	Table Receiving Briquette.
a	Ventilator.
b	Steam Engine.

Walter M. Stein,
Metall. Engineer,
825 Walnut St., Phila., Pa.

PORTABLE COKE CRUSHER, SCREEN AND DISTRIBUTOR.

The portable coke crusher, screen and distributor, of which we give an illustration, Fig. 91, was designed by C. M. Clarke, engineer. It is constructed for the purpose of utilizing the waste and small coke which accumulates around the yard, also coke that is unfit for shipping as furnace or foundry coke. The crusher is intended to be run along a track in front of the ovens, or wherever convenient, where the refuse coke accumulates, and the chutes for the various sizes are arranged so as to distribute the product in piles, as shown in the diagram, leaving the various sizes in the most convenient location with regard to the track for loading. By the use of such a portable crusher around works of almost any capacity, many hundreds of tons of coke that would otherwise be wasted may be utilized and sold for an increased price over the large coke. The entire mechanism, consisting of boiler, engine, adjustable crushing rolls, perforated boot to cleanse from dust, elevator, chutes, screen, shafting, pulleys, belting, etc., is mounted on a frame of steel and rests on four flanged wheels running on a standard gauge track. It can be easily hauled by one mule, or a mechanical motive power may be attached so as utilize the engine, by means of a clutch, to move the crusher from place to place.

The entire apparatus is automatic in its operation, receiving the large coke into the hopper and discharging it upon the ground at either side of the track, and between the rails in sizes of chestnut, stove and egg, and if desired additional sizes may be secured by arranging the screen at a slight extra cost. The attendance of but one man is necessary to feed the coke to the rolls, after which it takes care of itself; and the same man should be sufficiently intelligent to attend to the boiler and engine.

The capacity is easily 50 tons per day, and more if pushed. The various parts are strong and durable and not liable to get out of order, the only fixed expense for maintenance being the cost of screen wire, which must be occasionally renewed. It is claimed that the saving of this machine will ordinarily amount to its entire cost in one year or less. Estimates of cost and further particulars will be given by C. M. Clarke, 110 Diamond street, Pittsburg.

(*a*) Side Elevation.

(*b*) Plan.

(*c*) Plan of Chutes.

a Chestnut.

b Stove.

c Egg.

d Elevator.

e Rolls.

f Hopper.

g Engine.

h Boiler.

Chute.

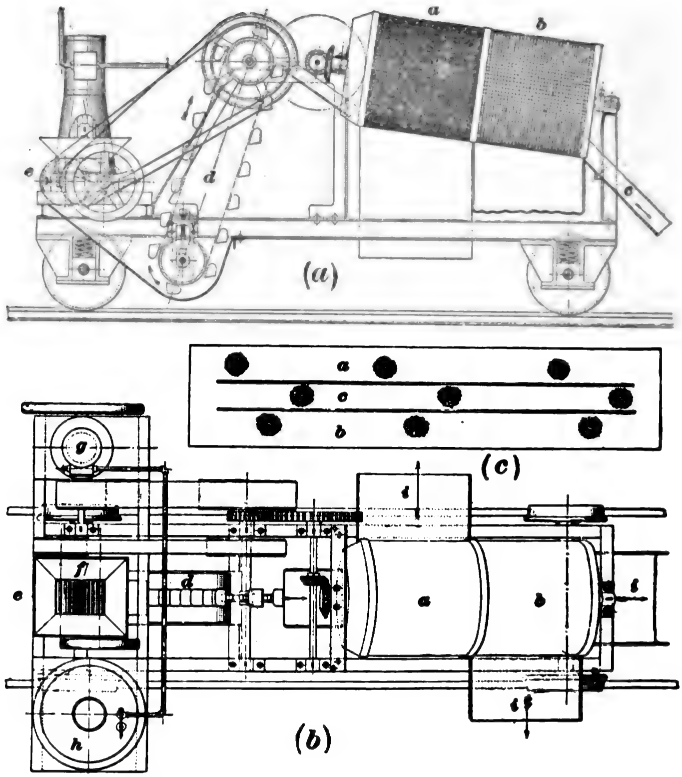


FIG. 91.—PORTABLE COKE CRUSHER, SCREEN AND DISTRIBUTOR.

SEMET-SOLVAY RETORT OVENS.

Report on Tests Made in Coking Connellsville Coal, and on Furnace Tests of the Coke Produced.

(Published by Special Permission of A. J. Moxham, Esq.)

A. J. Moxham, Esq.,
President, The Johnson Company,
Lorain, Ohio.

Dear Sir: In harmony with your instructions, dated March 26, 1895, I have conducted a series of experiments of coking Connellsville coal in Semet-Solvay retort ovens, at the works of the Solvay Process Company, near Syracuse, New York State.

The coke made in the ovens was shipped to the large blast furnace of the Buffalo Furnace Company, at Buffalo, New York, and its value, as a metallurgical fuel, tested in this blast furnace in comparison with the best quality of the Connellsville Bee-Hive oven coke, from the H. C. Frick Coke Company.

The main scope of these practical experiments was to determine, from actual accomplished work, the relative economies of the manufacture of coke in these two types of coke ovens, with their comparative calorific values in the work of manufacturing pig iron in a modern well-equipped blast furnace.

At this time, considerable attention is being directed to the economies in the manufacture of coke, with the saving of by-products, in retort or closed ovens.

This investigation is stimulated by the more recent improvements made in the construction of these ovens, mainly along the elements of securing good metallurgical coke by increased internal heat in the ovens, in the profits secured by saving the by-products of tar and ammonia, and by the increased percentage of coke made from the coal, reducing in proportion, the percentage of impurities in the coke.

In addition to these, the plan of these ovens has been simplified and the cumbersome and expensive regenerators and recuperators omitted; increased oven heat has been secured by thinning the inside walls through which the flue heat is transmitted into the coking chamber of the oven.

With the use of the best coking coals, the competition between the open and closed ovens is quite close and difficult of exact determination. Other things being equal, the main effort in the manufacture of metallurgical coke in the retort ovens, is to equal in calorific value, in blast furnace work, the standard Bee-Hive oven coke.

But in the manufacture of coke from the lower qualities of coals, especially those low in fusing matters, the narrow ovens have undoubtedly established their superior value in this respect.

The large cost of the retort ovens, as compared with the open or Bee-Hive, is the main barrier to their more rapid introduction. This is as $3,100 in the former to $325 in the latter.

To make the tests in a fairly comprehensive plan, 2058$\frac{1300}{2000}$ tons of Connellsville coal was shipped from the Valley mines of the H. C. Frick Coke Co., to Syracuse, for the initial coking test in the small experimental plant of 12 Semet-Solvay ovens at this place. These coking tests, as well as the subsequent blast furnace ones, were made with great care, as the importance of such determinations evidently demanded. It was the first time in the industrial records that Bee-Hive and Retort oven coke, from Connellsville coal, were compared, as to economy in cost of coking and relative value in blast furnace work, on fairly equated conditions.

The following analysis of the Connellsville coal used in the coking tests at Syracuse, in the Semet-Solvay retort coke ovens exhibits a fair average of the coal used.

Moisture, 212° F	0.84%	
Volatile Combustible Matter	31.60	
Fixed Carbon	59.86	
Ash	7.70	100
Sulphur	0.82	
Phosphorus	0.008	

The theoretic percentage of coke that can be obtained from the above coal is 68.00%. This assumes that no fixed carbon is consumed in coking and that no carbon is deposited from the tar gas in the oven. In the modern Bee-Hive oven, 12 x 7 feet, some of the fixed carbon is consumed in the oven, by the admission of air. At the same time the percentage of its coke is increased by the bright glaze of deposited carbon.

Two very careful tests were made to determine the percentage of coke made in the Semet-Solvay oven from Connellsville coal.

No. 1 test charge, 9,200 lbs. of coal, producing 6,580 lbs. large coke, 164 lbs. breeze and 256 lbs. dust and refuse.

No. 2 test charge, 9,000 lbs. coal, producing 6,349 lbs. large coke, 80 lbs. breeze and 198 lbs. dust and refuse.

	Test No. 1.	Test No. 2.
Large Coke	71.52%	70.55%
Breeze	1.78	0.88
Refuse, Pitch, &c	2.63	2.20
Total Coke	73.30	71.43
Average Large Coke	71.035%	

From accurate determinations of the percentage of furnace coke produced from Connellsville coal in the Bee-Hive and Semet-Solvay coke ovens, it was found as follows:

Bee-Hive	66% of Large Coke.
Semet-Solvay	71% " "

Taking the theoretic coke at 68%, it is evident that a loss of 4.22% of carbon has been made in coking in the Bee-Hive oven.

The Semet-Solvay, considered from the same standard, has gained 4.41% of carbon ; or a total gain of 8.63% of carbon over the Bee-Hive product.

In the Bee-Hive, however, the carbon deposit consists of a bright silvery coating, affording efficient protection to this fuel, from carbon dioxide gas, in its descent in a blast furnace.

The carbon deposit in the Semet-Solvay oven is a dull colored deposit of carbonaceous matter from the tar of the coal in coking. Much more carbon is deposited in the Bee-Hive oven than in the Solvay, but at the same time much more carbon is consumed in the open oven.

The Semet-Solvay oven is 30 feet long, 16½ inches wide inside coking chamber, and five feet six inches high.

The accompanying cross-section will show its general features.

It is constructed with dividing walls, arches and superstructure of red brick. It is noticeable that the flue tiles with their connecting arch, composing the coking chamber, are entirely independent of and separate from the red brick encasing structure. This secures freedom and room for expansion in the lining fire brick work of the coking chamber.

The 16-inch dividing and sustaining walls perform a double office, by supporting the structure and in storing heat. The slight cooling of the oven during the few minutes occupied in discharging the coke, is quickly restored by the heat stored in these encasing red brick walls.

The 2¾ inches in thickness of the inside face of the flue tiles transmits the heat from the combustion of the returned gas in the horizontal flues of the oven. The circuit of this heat is continuous in one direction and can be regulated at pleasure.

The hot gas from the ovens is carried under boilers to generate the necessary steam for the condensing plant, and for the engine in discharging the coke from the ovens.

The surplus gas can be used in lighting the works, or in any other way that may be required.

The horizontal flues in this oven can be readily examined and cleaned. They convey the heat in an even and direct manner, avoiding any liability to the injurious concentration of heat that is sometimes found in vertical flued ovens.

In considering the economies of this type of oven, it is important to inquire into its wearing properties. It is evident that the red brick walls, arches and superstructure are quite permanent, requiring no special attention in their repairs. The fire brick flue lining of the oven is the most liable to breakage and wear.

The twelve ovens at Syracuse have been in use about two years, and are now in good condition. During this time one end flue tile had to be replaced from a crack found in it. It is quite evident that the end flue tiles are liable to break or crack from the frequent changes in temperature at the doors of the ovens.

The inside flues are kept in a nearly uniform heat and are not so liable to crack.

As the coke is cooled on the outside of the oven, the difference in temperature inside should not seriously affect the life of the flued lining tiles.

In case of crack or breakage of these jointed lining tiles, their renewal at the ends of the oven can be made at a small cost and in a short time. The renewal of the inner flues will require the cooling of the oven as well as the ovens on either side of it. This is the most serious aspect of repairs, involving considerable expense in time and labor. It may be said, however, that the renewal of the inside tiles is infrequent.

The coking test in these ovens was conducted mainly to determine the minimum time required with maximum heat to produce good blast furnace coke. The tests covered the several times for coking from eighteen to twenty-six hours. It appeared that with well sustained oven heat, good blast furnace coke could be made in twenty hours. This was the standard minimum time used in producing the coke for furnace test. Some coke was made by continuing it in oven twenty-six hours. This produced a bright hard coke evidently equal in hardness of body to the Bee-Hive coke of seventy-two hours.

From subsequent experience in the furnace test it is quite probable that 23 to 24 hours would secure a firmer coke, that would bear faster furnace driving.

The coking tests began April 16, and closed May 17, 1895.

As before noted, there are only 12 Semet-Solvay ovens at the Solvay Process Works, at Syracuse, N. Y.

The analyses of Connellsville and Solvay cokes, made at the laboratory of the Buffalo Furnace, by Mr. O. O. Laudig, chemist, are as follows:

	Connellsville.	Solvay.	
Moisture, 212° F	0.19	1.25	
Volatile matter	1.17	1.61	
Fixed carbon	89.02	86.66	
Ash	9.62	10.48	100
Sulphur	0.90	0.77	

Analyses of Connellsville coal and the coke made from it in Semet-Solvay ovens, from laboratory of the Solvay Process Company, by Mr. J. D. Pennock, chief chemist, are as follows:

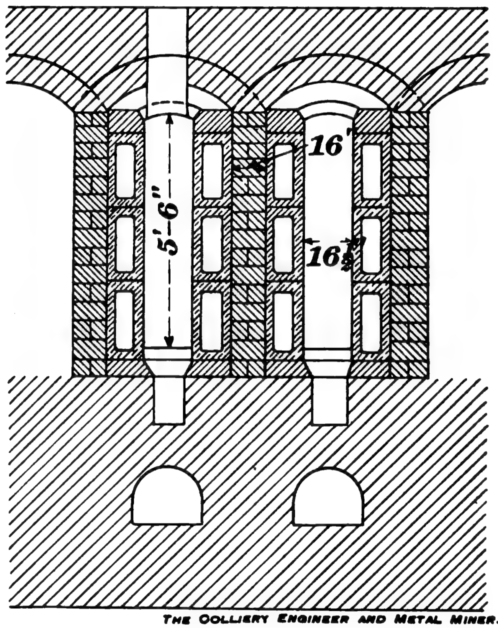
	No. 3.		No. 9.		Breeze.
	Coal Used.	Coke Made.	Coal Used.	Coke Made.	
Moisture 212° F	0.47	0.20	0.00	0.07	4.73
Volatile Matter	30.46	2.52	29.02	1.85	
Fixed Carbon	62.92	87.48	61.61	87.07	78.57
Ash	6 62	10.00	9.37	11.08	16.70
Sulphur	0.90	0.85	0.77	0.75	....
Phosphorus	0.025	0.037	0.017	0.023	....

In several tests in these ovens the coal was moistened with 1%, 2%, 3%, and up to 5% of water, without apparent change in the quality of the coke produced, or in the quantity produced from this coal.

The effect of the temperature of the oven in the manufacture of coke is well understood. For dry coals, a quickly applied high temperature produces the best possible coke. In the case of the richer coals, such as the Connellsville, a more moderate heat secures the best results in the coke.

During the progress of coking at Syracuse, in the Semet-Solvay ovens, frequent tests of the temperature in the flues and interiors of these ovens were determined by the use of the German Sègar Cones. These have been recorded as follows:

East flue, top		2130° F.
West " "		2112° "
East " center		2222° "
West " "		2354° "
East " bottom		2138° "
West " "		2174° "
Within the mass of coke		1994°
Above " " "		1958°



CROSS SECTION SEMET-SOLVAY OVENS.

Temperature tests taken in the Bee-Hive oven immediately above the coking coal, gave the maximum heat 2778° F. from 48 hours or furnace coke.

From the foregoing it will readily be seen, that in the coking operations of these ovens, the application of heat is quite different. The long time required in drawing the coke from the Bee-Hive oven, reduces its temperature to 300° or 400° F. The operation of coking, therefore, begins under a mild heat, increasing gradually until the high maximum is reached midway in the operation, producing a hard-bodied coke with full developed cells.

On the other side, the rapid discharge of the coke in the Semet-Solvay oven, by a steam engine pusher, reduces the temperature very slightly, and

on closing the doors of the oven for a fresh charge of coal, the average heat is rapidly restored. The oven heat is, therefore, applied quickly and maintained throughout the time of coking.

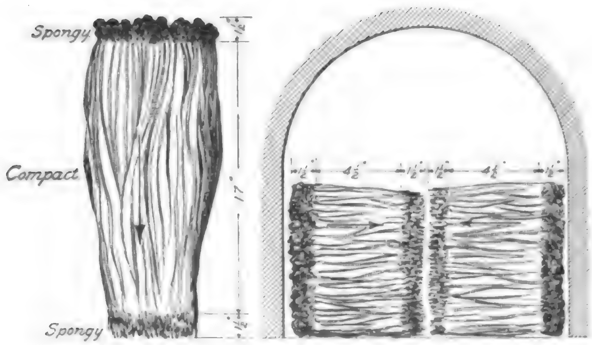
In the open or Bee-Hive oven the coking of the charge of coal begins on the upper horizontal surface, reaching down through the charge gradually to the floor of the oven. The coke crystallizes in a vertical columnar structure in surfaces at right angles to the horizontal plane of the oven.

In the Semet-Solvay oven the planes of crystallization are at right angles to the vertical side walls of the oven, and consequently, in horizontal postures. The coking begins at the oven side walls, moving gradually to the central longitudinal plane of the oven, where a line of demarcation is developed in a shelly section of coke of inflated physical structure.

The pressure of the charge of coal in the narrow oven compresses the cell structure of its coke, making it more dense than the broad oven with shallow charges.

The general structure of Bee-Hive and Semet-Solvay coke will be noticed in the following sketches:

BEE-HIVE COKE, 48 hours. SEMET-SOLVAY COKE, 20 hours.



Dense Coke..................3 inches
Average Coke................9 "
Spongy Coke.................3 "
Arrows show direction of coking.

A Bee-Hive oven of 12 feet in diameter, taking the inflated structure of coke at top and bottom of charge at 3 inches, will afford 85% of good coke and 15% of spongy coke.

The Semet-Solvay oven makes 3 inches of spongy shattered coke in the middle of the charge, producing 81% of compact coke and 19% of spongy coke.

The Bee-Hive oven will make an average of 2 net tons of coke per day. The Solvay will afford a product of 4 tons per day.

The following table will exhibit in detail the physical and chemical properties of cokes made in these typical ovens:

FULTON'S TABLE EXHIBITING THE PHYSICAL AND CHEMICAL PROPERTIES OF COKE.

Revised Series.

LOCALITY.	Grammes in One Cubic Inch.		Pounds in One Cubic Foot.		Percentage by Volume.		Compressive Strength per Cubic Inch, ¼ Ultimate Strength.	Height of Furnace Charge, Supported Without Crushing.	Order in Cellular Space.	Hardness.	Specific Gravity.	CHEMICAL ANALYSIS.						REMARKS.	
	Dry.	Wet.	Dry.	Wet.	Coke.	Cells.						Fixed Carbon.	Moisture.	Ash.	Sulphur.	Phosphorus.	Volatile Matter.		
Connellsville Bee Hive.........	12.51	21.62	47.69	82.20	43.93	56.07	272	108	1	3.0	1.74	86.88	0.79	11.54	0.695	0.005	1.31	Standard Average.	a.
" "	13.66	23.31	52.02	88.72	43.91	56.09	315	125	1	3.0	1.80	89.02	0.19	9.62	0.94	0.019	1.17	Adelaide, H. C. F. Co.	b.
" Semet-Solvay	16.48	24.29	61.59	92.47	56.16	43.84	......	......	......	......	......	......	......	......	......	......	......	Buffalo. Section at Oven Walls.	c.
" "	14.92	23.47	55.80	89.51	47.61	52.39	......	......	......	......	......	......	......	......	......	......	......	Intermediate Section.	
" "	15.40	25.48	59.29	96.20	46.60	53.40	......	......	......	......	......	......	......	......	......	......	......	Middle Section.	
" " Average	15.43	24.18	58.12	91.92	49.49	50.51	370	147	1	3.0	1.90	86.66	1.25	10.48	0.77	0.018	1.61	Used at Buffalo.	d.

Note.—The above cokes were all made from Connellsville coal. The coke used at the furnace test at Buffalo consisted of Bee-Hive and Semet-Solvay, made in the open and retort ovens. a, T. T. Morrell, Chemist; b, O. O. Laudig, Chemist, Buffalo Furnace Co.; and d, J. D. Pennock, Chief Chemist, The Solvay Process Co., Syracuse, N. Y.

It will be noted that the Connellsville coke, used at the Buffalo furnace during the test, was from the Adelaide works of the H. C. Frick Coke Company.

The coal used in making coke in the Semet-Solvay ovens at Syracuse, N. Y., was shipped from the Valley mines of the H. C. Frick Company.

The physical determinations of the Adelaide coke exhibit a most excellent structure, equalling the standard coke of this region.

The analysis shows its superior chemical purity, excelling in this respect the standard coke.

The physical tests of the Semet-Solvay coke exhibit the increase of density in the retort coke as compared to the Bee-Hive. These are typical examples and indicate in a clear and definite manner the condition of coke made in these two principal types of coke ovens. The increase of cell space will be noticed in the Solvay coke, from the walls of the coking chamber to the middle of the oven.

The average increase in density of the Solvay coke over the standard Bee-Hive is 12.7%. The compression of cell structure is 11½%.

The chemical analysis shows a fairly clean coke, but exceeding the Adelaide coke in the percentage of ash.

This analysis discloses the fact that the Solvay coke retained 1.61% of volatile combustible matter, as against only 1.17% in the Adelaide coke, an increase of 3.76%. This indicates the requirement of a longer time in the coke oven, or an increase of heat to reduce this volatile element.

Retort coke should be somewhat harder bodied than open oven or Bee-Hive coke. But in the foregoing table they are just equal, which sustains the demand for more oven heat or longer time in coking in the retort oven.

It is also important to reduce the percentage of the inflated sections of coke in the middle of the oven. It is submitted that by widening the oven chamber to 20 inches, the ratio of shattered to solid coke would be largely reduced.

The following tabulated statement will exhibit the relative costs and economies in plants of Bee-Hive and Semet-Solvay coke ovens, to produce 300,000 net tons of blast furnace coke per year, using Connellsville coal:

TABLE EXHIBITING THE RELATIVE ULTIMATE ECONOMY OF PLANTS OF BEE-HiVE AND SEMET-SOLVAY COKE OVENS.

NAME OF OVEN.	Cost Per Oven.	Cost of Condensing Plant, Per Oven.	Total Cost Per Oven.	Daily Output Per Oven, Net Tons.	Number of Ovens to Make 300,000 Net Tons Per Year.	Total Cost of Plant.	Interest on Investment 5% Per Year.	Interest Per Ton of Coke.	Sinking Plant in 20 Years, Per Ton.	Labor Making Coke and Saving By-products.	Total Cost Per Net Ton.	Percentage of Coke Produced.	Value of Units of Coke Over 66%.	Value of By-products Per Net Ton Coke.	Net Ultimate Cost of Coke Per Ton.	REMARKS.
Bee-Hive	$825.	......	$825.	2.0	500	$162,500	$8125.	$0.02¾	$0.02¾	$0.35	$0.40½	66%	....	....	$0.40½	By-products not saved.
Semet-Solvay	1550.	$1550.	3100.	4.00	250	775,000	38750.	0.12 9/10	0.12 9/10	0.40	0.65 8/10	71%	$0.07	$0.40	0.18¼	By-products saved.

NOTE.—The by-products are estimated as affording net profits as follows: Ammonia sulphate, 25 cents per net ton of coke made; tar, 6 cents; and surplus gas, 9 cents.

In the above comparison of relative cost and work of ovens no estimate has been made of the cost of repairs for each type of coke oven. It is assumed that these will not vary much in a term of 20 years.

The "breeze" from handling the Solvay coke is much less than that from the Bee-Hive coke. Little waste is found in careful handling of Semet-Solvay coke.

The Buffalo furnace, of the Buffalo Furnace Company, is a modern blast furnace, 18 feet at bosh and 80 feet high. It has three hot blast stoves, 18 x 70 feet, of the Cowper-Kennedy type. The blowing engines have surplus power, and can increase the pressure of blast to meet the requirements of different densities of fuels.

The plant is located on the bank of the Buffalo river, on the west end of Hamburg street, and receives its ore stock direct from the lake boats.

The limestone for fluxing comes from Canada, from the upper members of the Helderberg formation, and is most excellent for this purpose. Many of its sections are highly saturated with petroleum.

The composition of limestone is as follows:

Carbonate of lime	97.45%
Carbonate of magnesia	1.40%
Oxide of iron, alumina, etc	0.50%

The coke used at this furnace is supplied by the H. C. Frick Coke Company. It was especially noticed as the very best quality of furnace coke; evidently it had been carefully selected, as no "black ends" were visible in the supply examined. It was, therefore, quite manifest that the best Connellsville Bee-Hive coke would be used in the competitive test with the Semet-Solvay coke.

The whole furnace plant is ably managed by Mr. F. E. Bachman.

Immediately before the commencement of the coke tests, the furnace was banked a short time to give opportunity for cleaning the hot blast stoves. It was assumed that a few days after resumption of work, the furnace would regain its normal condition. It did not, however, attain uniform work throughout most of the time of these tests, but it is proper to submit, that the irregularities in its working were about equally distributed over the periods of the use of Bee-Hive and Semet-Solvay cokes; possibly somewhat more during the use of the Semet-Solvay coke.

This furnace is run chiefly to make open foundry pig iron, and this was its product during the time of these coke tests, with some exceptions, when a denser metal, denominated "holly," was produced.

The mixture was changed slightly during the tests, but was on an average, as follows:

Marquette iron ore	17,000 lbs.
Winthrop iron ore	878 "
Rex iron ore	636 "
Florence iron ore	1,050 "
Queen iron ore	672 "
Total	20,236 lbs.

This mixture gave an average product of 57.29% of foundry pig iron.

The weights of the coke charges averaged as follows:

Bee-Hive, Connellsville	10,923 lbs.
Retort, Semet-Solvay	11,830 "

The limestone charges averaged as follows:

For Connellsville coke	3,300 lbs.
For Semet-Solvay	3,600 "

The general table of blast furnace operations will exhibit the results of these tests, with Connellsville Bee-Hive and Semet-Solvay cokes.

TESTS OF BEE-HIVE AND SEMET-SOLVAY OVEN COKE, FROM CONNELLSVILLE COAL, MADE IN THE BUFFALO FURNACE, MAY, 1895.

Date, 1895.	Kind of Coke.	Furnace Charges—24 Hours, Pounds.			Iron Made, Tons—2,300 lbs.					Total Tons Daily.	Stock Per Ton of Metal.			Average Pressure of Blast.	Heat of Blast at Furnace.	Gases, Top of Furnace.		Ratio, CO_2 : CO.	Average.	Silica in Metal.	Cinder.		REMARKS.
		L.S. Ore	Lime-stone.	Coke.	No. 1.	No. 2.	No. 2, Plain.	No. 3.	Ragged.		Ore.	Lime.	Coke.			CO_2.	CO.				SiO_2.	Al_2O_3	
														lbs.	O.F.	%	%			%	%	%	
May 12		920,760	158,000	524,300	8	92	110	16	9	235	3918	672	2231	7¾	1088	10	21.90	1:2.19		3.0	30.82	22.40	Furnace working irregular.
" 13		968,540	167,000	546,150	6	94	91	11	5	207	4679	806	2657	7¾	1098	8.8	22.536	1:2.56		2.86	31.20	20.00	Furnace working irregular.
" 14	Connellsville Bee-Hive.	1012,960	171,600	568,000	6	68	117	62	6	259	3911	662	2208	8	1125	9.0	23.20	1:2.59	1:2.47	1.91	36.80	20.06	Improved working.
" 15		972,000	165,000	546,150	8	66	138	34	7	253	3845	652	2174	8⅛	1159	10.2	26.60	1:2.60		2.22	37.20	20.04	Becoming more regular.
" 16		385,820	67,800	218,460	0	69	61	110	5	245	3600	643	2184	7⅛	1226	8.5	21.00	1:2.47		2.32	32.44	21.30	Cooled furnace, reduced lime.
" 16		489,380	89,800	295,730	......	......	......	......	......	......	......	......	......	......	......	......	......	......		......	......	......	Furnace cool.
" 17		890,880	158,720	532,350	0	94	95	50	5	244	3248	650	2181	8	1167	9.1	21.9	1:2.40		3.05	29.00	21.15	Slipping—not down to regular work.
" 18	Semet-Solvay Retort.	901,800	157,500	532,350	0	61	99	66	5	231	3904	682	2304	7⅛	1218	9.1	21.8	1:2.28	1:2.27	1.98	33.80	17.70	Two slips to-day—cooling furnace.
" 19		854,700	152,480	496,860	10	113	84	16	5	228	3749	669	2179	6½	1234	10.7	23.5	1:2.10		2.25	30.40	18.10	Furnace gaining heat.
" 20		966,900	150,800	496,860	18	99	73	12	5	207	4140	728	2475	7⅛	1240	9.4	21.0	1:2.23		2.49	30.15	19.70	Improved working.
" 21		707,580	130,575	421,468	45	148	133	25	9	260	2721	508	1621	7	1251	8.8	20.7	1:2.35		2.42	33.80	16.00	Working steadily.

These general results require and will be adjusted subsequently, so as to give to each test the true results of its work as accurately as can be determined.

The test of the Connellsville Bee-Hive coke began May 12, at 6 o'clock A. M., and closed May 16, at 5 o'clock P. M.

The Semet-Solvay coke test began at the close of the Bee-Hive coke and ended May 22, at 2 o'clock A. M.

Approximately five days were alloted to each kind of coke.

Samples of each kind of coke were submitted to severe tests for moisture, in a neighboring foundry core oven, and resulted as follows:

Connellsville Bee-Hive coke, 973½ lbs. dried to 956 lbs.; loss, 1.830%.

Semet-Solvay coke, 1,174¼ lbs. dried to 1,114¼ lbs.; loss, 5.385%.

The heat of the core oven was not determined, but it was estimated approximately as approaching 300° F. ±

Referring to the analyses of the Bee-Hive and Semet-Solvay cokes, made in the laboratory of the Buffalo Furnace Company, and at the Solvay Process Works, it will be noted that the Bee-Hive coke has been made from much cleaner coal than that from which the Solvay was made.

Taking the average of these two determinations for the Semet-Solvay coke, would give it, in round numbers, 88% of carbon, and the Bee-Hive 89% as charged into the furnace.

Equating these cokes for the moisture, it will reduce the carbon in the Semet-Solvay coke to 84% and the Bee-Hive to 88% of efficient available carbon for furnace use, allowing for the volatile matters in these cokes.

The table shows that there was little waste from soft coke, as the relations of the two gases, CO_2:CO, were found to be as 1: 2.47 in the Bee-Hive coke, and as 1: 2.27 in the Semet-Solvay product. Sir I. Lowthian Bell found the relations of these gases in a large test of Durham Bee-Hive coke as 1: 2.28, and in Simon-Carvès' retort oven coke as 1: 3.32.

The heat in the furnace during these tests was fairly well sustained. Closing the Connellsville Bee-Hive test a disarrangement of the stock scale reduced the limestone, causing a slight lowering of temperature of furnace at the opening of the Solvay coke test.

The analyses of six casts of Bee-Hive and Solvay iron will afford comparison of heat of furnace and quality of pig metal produced.

	Connellsville Coke.	Semet-Solvay Coke.
Graphitic carbon	3.76	3.60
Combined carbon	0.17	0.18
Silicon	2.77	2.15
Phosphorus	0.283	0.284
Sulphur	0.049	0.039
Manganese	0.78	0.78

All this metal No. 2 pig.

The following condensed statement will show the stock used and pig iron produced from Bee-Hive and Semet-Solvay cokes, during these tests:

	Bee-Hive Coke Test.	Semet-Solvay Coke Test.
Iron ore used	4,260,080 lbs.	4,711,190 lbs.
Limestone used	729,400 "	870,700 "
Coke used	2,403,060 "	2,775,613 "
Pig metal made	1,122 tons (of 2,300 lbs.)	1,205 tons
Coke per lb. of iron	.956 lbs.	1.028

Equating the conditions of these cokes and eliminating excess of moisture, the coke per pound of iron will be for Bee-Hive .938 lb., and for the Semet-Solvay .972 lb.

When the further fact is taken into consideration that the Semet-Solvay coke contained an average of 10.17% of ash, whilst the Bee-Hive had only 9.62% of this impurity, the quantity of each kind of coke to smelt one ton of foundry metal, is substantially equal, and the amount of coal used as Semet-Solvay coke is proportionably reduced.

Introducing the factor of relative proportions of coke made from a pound of coal in the two types of ovens, the comparison becomes as follows:

	Bee-Hive	Semet-Solvay.
Coal per pound of iron	1.421	1.389

The different grades of foundry metal made during the five days' test by each kind of coke is as follows:

	No. 1.	No. 2.	No. 2 plain.	No. 3.	Ragged.	Total.
Bee-Hive	20	357	480	237	28	1122
Solvay	73	487	461	156	28	1205

It will be noted that the Solvay coke products in pig iron Nos. 1 and 2, give 560 tons, and the Bee-Hive 377 tons. The lower products of Solvay coke in No. 2 plain, No. 3 and Ragged, give 645 tons, against 745 tons from the Bee-Hive coke.

The difference, therefore, in the heats afforded in the metal made by Bee-Hive and Solvay coke is fairly in favor of the latter.

The most vital inquiry in these competitive tests, consists in the relative physical properties of these cokes to stand rapid "driving" in the furnace. It was found that usually the Connellsville Bee-Hive coke could take a blast from fifty-one revolutions of engine, whilst the Solvay coke reached its maximum at forty-eight revolutions, a reduction of 5.88%.

The tabulated statement of furnace operations during these tests shows that the largest output of pig iron from Bee-Hive coke was 259 tons, and from Solvay coke 244 tons; a decrease in daily product of the latter of 5.79%, which is in harmony with the reduction of blast when using the Solvay coke. It is true, however, that the Connellsville Bee-Hive coke requires to be reduced occasionally to forty-eight revolutions in the blast, but this is the exception rather than the rule.

The analyses of the gases at top of furnace show that there is no loss in the Solvay coke from dissolution in its passage down the furnace, from carbon dioxide: but on the other side it resists this gas with more firmness than the Adelaide coke.

No temperature tests were taken as to the heat of the gases at top of furnace, but the relations of CO_2 to CO are assuring that no wastage from dissolution from the soft or spongy portions of the fuel had taken place.

From the denser physical properties of the Solvay coke, it was anticipated that an increased pressure of furnace blast would be required to develop its best qualities; but in this we were somewhat disappointed, as the furnace test reversed the order of blast in a direction just opposite the one anticipated.

The conclusion is evident, that the Solvay coke requires more heat or more time in the oven, to enable it to stand the blast in "driving" the furnace equal to the Bee-Hive coke.

In making the coking tests at Syracuse, all needed facilities were cheerfully afforded by the chief officials of the Solvay Process Co.

To Mr. Thomas Morris, Superintendent of the Coke Ovens, I am indebted for many helpful suggestions and other favors.

I append letter from Mr. E. N. Trump, General Manager and Chief Engineer of the above company, affording data bearing on these ovens.

Also letters from Mr. W. H. Blauvelt, Fuel Engineer, who has greatly aided me in grouping statistics.

During the progress of these tests at Buffalo, we were favored with the presence of Mr. W. B. Cogswell, Managing Director of the Solvay Process Company, as well as by Mr. W. H. Blauvelt, Fuel Engineer, of this company.

The Carnegie Company was represented by Mr. James Scott, the Superintendent of the Lucy Furnaces in Pittsburg; also Mr. Charles McCrery, Manager of the Dunbar Furnaces.

Mr. T. B. Baird, Vice-President of the Buffalo Furnace Company, and its Manager, Mr. F. E. Bachman, afforded full opportunity to secure results of tests. Mr. Baird was especially courteous in extending to the visitors many favors.

Mr. W. T. Richards, of Cleveland, who directs the management of the M. A. Hanna Furnaces, was very helpful in these tests.

In conclusion it may be submitted, that, whilst the testing time of these cokes in the blast furnace has been necessarily limited, yet it has afforded some reliable indications of the relative values of Retort and Bee-Hive coke in the manufacture of pig iron.

It has been established, that the denser coke of the retort oven could not be "driven" as fast in the furnace as the more open celled Bee-Hive coke, in relations of 48 to 51.

It has yet to be shown that the denser retort coke, hardened by increased heat and time in the oven, can be made to stand a blast, proportionally stronger than that of the Bee-Hive fuel, to equal the furnace output of the latter in pig metal.

In the relations of density of fuel to speed in a blast furnace, the fact has been definitely settled, that other conditions being equal, the speed is in proportion to the density of the fuel.

This is found in the use of anthracite coal (which is a natural coke), in blast furnace operations, in its slow calorific energy, as compared with open-celled Bee-Hive coke.

The output in pig iron of the former to the latter is as 3,000 to 8,000 tons per month, or as 1: 2.66.

The retort oven, however, affords advantages, as, from the Connellsville coal, it will yield 71% of large coke for furnace use, against 66% of a similar product of the Bee-Hive.

This, with the saving of by-products by the retort oven, compensates for the difference in its energy or speed in a blast furnace, as compared with the Bee-Hive fuel.

The Semet-Solvay coke oven has been designed under correct principles, as regards wearing properties and output.

Its most distinguishing property is in its rapid work in coking, which is 30%± shorter in time than its chief competitors.

Very respectfully,

JNO. FULTON,
Mining Engineer.

JOHNSTOWN, PA., July 2, 1895.